UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Addressing the Challenges of Plastic Pollution, including in the Marine Environment, Using Circular Economy Methods

CONSIDERATIONS RELEVANT TO SUCH AN APPROACH

A working paper

UNIDO – United Nations Industrial Development Organization
Circular Economy and Resource Efficiency Unit

Vienna, Austria, April 2019, updated November 2023

Executive summary

PREFACE

Plastics are versatile materials, being inexpensive, light, easily shaped and durable, which have brought immeasurable benefits to many areas of life. They are used in numerous industrial sectors, including packaging, health care, construction, automotive, aviation, agriculture, logistics and storage, consumer goods, clothing and many more. As a result, plastic products have seen a huge and rapid rise in production, from almost nothing in the early 1950s to a little over 400 million tonnes/year as of 2015, with no signs of abatement in the rate of growth: it has been estimated that under a Business As Usual scenario, an extra 26 billion tonnes of plastic products could be produced by 2050.

by 2050

extra

26 bn

tonnes of plastic products could be produced

Primarily made from fossil fuels, plastic materials are valuable and embody our world's limited natural material resources (in addition to oil, much energy, mostly non-renewable, and water) and come with sunk investment costs that may be reused to create fresh economic value. Yet this value is not reflected in their fate. In 2015, a little over 300 Mt of plastic waste was generated, amounting to 74% of the total primary plastics production in that same year. For certain product categories, this percentage was even higher: 97% and 88% for plastic packaging and plastic consumer and institutional goods, respectively, reflecting the short to very short lifetimes of many of these products. Very little of this plastic waste is being recycled and reused in new products. Of the 8.3 billion tonnes of virgin plastics produced between 1950 and 2015, only 30% are still in use. The remaining 70% have become waste. Only a little under 2% of this waste has been recycled. Of the remainder, 14% has been incinerated and 84% has either been deposited in landfills and dumps or is polluting the terrestrial and marine environments. This constitutes a huge loss in economic terms and is alarming with respect to the potential harm that this could mean to humans, animals and plants in our ecosystems.

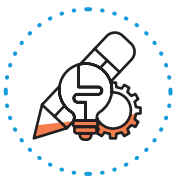
The concerns raised by the rapidly growing problem of plastic pollution, including in the marine environment, have recently led to the decision to develop an international legally binding instrument to tackle this plastic pollution. An Intergovernmental Negotiating Committee

has been convened with the task of developing the instrument. Discussions in the Committee are ongoing.

CIRCULAR ECONOMY PRACTICES FOR COMBATING PLASTIC POLLUTION, INCLUDING IN THE MARINE ENVIRONMENT

The objective of this paper is to contribute to the ongoing discussions, highlighting how resource efficiency and circular economy concepts can provide useful pathways forward. The paper focuses in particular on packaging and other single use plastic products, which make up the largest portion of today's plastic pollution. The adoption of circular economy practices, in conjunction with optimisation of landfill management, will help to substantially reduce the amount of these types of plastic products most likely to leak into the terrestrial and marine environments.

All the actors along the value chain of plastic packaging and other single use plastic products have circular economy practices which they can adopt. In the production stage of the manufacture of these products, two circular economy practices predominate.



Product design is fundamental to circularising any product, since products must be designed to easily and at least cost pass through the cycles which are relevant to them. With respect to plastic packaging and other single use plastic products, product designers could consider the following design options:

a. scrutinising the necessity of plastic packaging (or of any other type of packaging), or the need to use single use plastic products;
b. selection of renewable, biodegradable and compostable materials to use instead of the plastic;
c. designing for the use of recycled plastic to make up at least a portion of the total plastic used;
d. selection of additives that are not or less toxic and/or do not interfere with the recycling processes;
e. designing for the use of less plastic in the product;
f. designing products that use one or a small number of polymers that are easy to separate during recycling.

Note that design decisions are intimately linked to the circular business model which a company will adopt with respect to circularising its products.

During the **manufacture** of plastic packaging and of the products using this packaging, as well as of other single use plastic products, factory management can implement the Resource Efficient and Cleaner Production (RECP) methodology to prevent loss of plastic raw materials and of the plastic products themselves into the environment (the RECP methodology can also be used to make manufacturing operations generally more resource and energy efficient).

During the various **transportation** stages which occur throughout the value chain – of raw materials to the points of manufacture, of the products from their point of manufacture to their point of sales, of discarded products to recycling

facilities, of recovered plastic to new points of manufacture – transporters can also use the RECP methodology as a circular economy practice for minimising the loss of products during transit as well as for minimising the use of tertiary plastic packaging which they use.

Many other businesses in the service sector are heavy users of single use plastic products. However, two stand apart because their "use" primarily consists of passing on the single use plastic products to consumers, who are then left with the problem of what to do with these products once they discard them. These are the **retail sector** and businesses offering **food and beverages** to go. Both of these have specific circular economy practices which they could adopt.

Retailers could consider the following circular economy practices for reducing the amount of plastic packaging they use:

a. eliminate the use of plastic packaging altogether, by, e.g., encouraging consumers to come with their own reusable containers;
b. reduce the amount of plastic packaging they use, by, e.g., selling products which normally include a lot of water in a concentrated liquid form instead, or as tablets, with the customer adding the necessary water at home;
c. switch the plastic packaging they use to packaging made from biodegradable or compostable materials.

Businesses offering food and beverages to go could also consider the same set of circular economy practices as for the retail sector, but tailored to their business models. Thus, they could:

a. eliminate the use of single use plastic products, by, e.g., encouraging customers to come with their own coffee mugs or by joining a programme offering reusable mugs;
b. reduce the amount of plastic used in their single use products, by, e.g., choosing to purchase their products from manufacturers which have light-weighted them;
c. switch to offering their customers single use products made of biodegradable or compostable materials, e.g., offering straws made with compostable materials.

In the **use stage**, consumers have a number of circular economy practices available to them to reduce the amount of plastic packaging and other single use plastic products they use. Decisions they make at the point of sale are particularly important in this case. They can choose purchasing options which reduce, if not eliminate, the amount of plastic packaging and other single use plastic consumer products they purchase. For instance, they can choose to do their shopping with their own reusable bags and containers (if the retail stores they use allow this), or they can join programmes which offer to deliver them their produce in reusable containers. Once they have used these plastic products for their original purpose, consumers can extend their useful lives by reusing them in a variety of ways; note, though, that the impact here will be modest, because of the limited way in which these products can be used. Once they have finished using these products, the main action consumers should take is to properly discard the products – this is taken up again below.

Note that while the focus here is on household consumers, all actors in an economy are also at least in part consumers. Businesses and other entities in the service sector purchase

goods which are packaged in plastic packaging or purchase other single use plastic products, and use them to deliver their services (e.g., the healthcare sector, the hospitality sector). Manufacturers also purchase goods which they use to make their products; at least part of these will come in plastic packaging. Farmers and other primary producers also purchase specialised single use plastic products or other goods to grow their produce; some of the latter will come in plastic packaging. The circular economy practices outlined above are equally applicable to these consumers.

Once plastic packaging and other single use plastic products have completed their useful life and are discarded, **recycling** is the circular economy practice of choice. The objective is to deliver back into the economy recovered plastic of a high quality that can be reused to manufacture new plastic products. There are two key requirements which have to occur upstream of the recycling to maximise the effectiveness of the recycling operations themselves. First, as many as possible of the discarded single use plastic products need to be **separated** out from the rest of the household waste which consumers are discarding (this is the category of waste to which most single use plastic products belong). This is best done at source by the consumers, but it does require waste separation programmes to be in place for them to use. If these are not in place, the separation will need to be done after mixed household wastes are collected, either mechanically or by hand; generally, this is not as effective since the resulting separated plastic stream is more contaminated and leads to a recovered plastic with a lower quality.

The second key requirement for proper recycling is that household wastes be widely **collected**. In developed countries, governments have put in place the necessary rules and regulations to govern collection and have developed specialised collection vehicles and other infrastructure to do it. As a result, the great majority of household wastes are collected. In developing countries, this governmental oversight is much weaker and much household waste is either not collected at all or only fitfully collected, resulting in much household waste being dumped. At the same time, where discarded products have a recognised value in the marketplace, private waste pickers have stepped in and can very efficiently collect these types of discarded products. Large numbers of people are involved in these informal operations, allowing them much-needed income. The trend is for developing countries to adopt the operational models used in the developed countries, which is squeezing out the informal waste pickers, who are losing their major source of income with no alternative available. Some reports indicate that this is having the unintended consequence of putting strong pressure on the new waste management infrastructures, resulting in their inadequate functioning. It has been argued that it would be better to formalise the informal waste pickers and integrate them into the new waste management infrastructures or into the new structures created by the move to circularity.

As for the recycling itself, currently the more common type of recycling operation is mechanical recycling. This operation is not very costly. Increasingly, however, plastic products, especially plastic packaging, are containing multiple polymers, and the current technologies have difficulties separating these different polymers from each other. The result is not very pure low-quality recovered plastic. In addition, mechanical recycling cannot currently separate out the various additives included in plastics. As a result, as a particular batch of plastic is subjected to recurring cycles of recycling, more and more additives, as well as other impurities, will accumulate in the material, increasingly reducing the value of the plastic as well as possibly making it more harmful to the health and safety of consumers. This puts a limit on the amount of times plastic can be recycled. An emerging alternative to mechanical recycling is chemical recycling. Here, chemical processes convert discarded plastic back to virgin feedstock for the production of plastics or other chemicals. Chemical recycling allows for the removal of additives and other impurities, but it requires considerably more effort and therefore energy input. It must always be remembered that while recycling may be economically and environmentally beneficial, it does not necessarily come at low risk to human health and the environment. In the specific case of recycled plastic, recycling operators can themselves become a serious source of terrestrial and marine plastic litter by allowing plastic materials to escape from their operations. Thus,

the promotion of recycling must go hand-in-hand with the development of the necessary regulatory framework and its enforcement, along with the needed training of operators on good operating practices.

With today's technologies, it is almost impossible not to have a plastic waste fraction that cannot be reused in making new products of the same quality as the original products. Downcycling (the production of lower-quality products) is an option for these types of plastic streams. One notable development in this regard is the emerging practice of using low-quality plastic materials as a component of road paving, or any other products expected to have a long lifespan. However, such products may allow potential leaks of microplastics and potentially eco-hazardous additives into the environment during use.

The report points to examples which already exist, in both developing as well as developed countries, of many of the circular economy practices that have been outlined above, as well as to examples where circular economy practices are in the process of being trialled. Government policies will be key to ensuring that such examples are scaled up and come into general use. While the menu of policies aiming to retain plastics in the economy for as long as possible will vary across countries, the strategies for designing them could be guided by the following core principles:

a. **"Closing the front door"** by preventing some products ever entering markets in the first place, e.g., bans on the production and/or sale of certain types of plastic packaging and other single use plastic products;
b. **Providing incentives for the perpetual use of plastic materials**, through a variety of actions ranging from support for R&D, to the creation of conditions for the development of technological solutions for enhanced recycling, to creating a level playing field for recycled (secondary) plastics, to facilitating investments in preferred technologies and businesses, to support for technology transfer, and to support for citizens' education;
c. **"Closing the back door"** by adopting measures that discourage leakage of plastic materials from the system, e.g., the creation of the necessary collection, sorting and separation systems and recycling facilities, measures for extending the responsibility for the end-of-life stage of products to the producers.

Final disposal, which is the least desirable option in a circular economy, will nevertheless continue to represent the main waste management solution for waste plastic packaging and the waste of other single use plastics for a good number of years to come, as economies undertake the transition to circularity. How well these wastes are managed in countries' waste collection, incineration, and landfilling operations will greatly influence how much plastic escapes into the environment, both terrestrial and marine.

IN THIS WORKING PAPER

This Executive Summary precedes a short introduction to the issue of plastics, especially plastic packaging and other single use plastic products (Chapter 1), which is followed by a discussion of the source and fate of these kinds of plastic products (Chapter 2). This is followed by a general introduction to the Circular Economy (Chapter 3). Chapter 4, by far largest chapter, discusses how the circular economy practices outlined in the previous chapter could be applied along the value chain of plastic packaging and other single use plastic products, considering the product design, manufacture, transportation, retail, use, and end-of-life stages. Examples are given of where the cited circular example practices are already being used or are being trialled. Possible policy responses are given for how to promote the scale-up of such examples. Recognising that final disposal of waste plastic packaging and other single use plastic products will continue for a while, the chapter closes with a brief mention of how waste management practices could be improved so as to minimise the leakage of plastic waste into the environment. Chapter 5 contains a summary of strategies proposed and some final thoughts on how loops could be closed in a circular plastics economy.


clear apple

Table of contents

EXECUTIVE SUMMARY 3

TABLE OF CONTENTS 9

GLOSSARY 10

1 INTRODUCTION 13

2 THE SOURCE AND FATE OF PLASTIC PACKAGING AS WELL AS OTHER SINGLE USE PLASTIC PRODUCTS 15

2.1 Plastics production and waste generation 15

2.2 Most commonly used polymers in plastic packaging 16

2.3 The use of additives in plastic packaging 18

2.4 The flow of plastic packaging and other single use plastic products from the economy into the environment 18

3 CIRCULAR ECONOMY – AN INTRODUCTION 19

4 CIRCULAR ECONOMY PRACTICES FOR ADDRESSING THE CHALLENGE OF REDUCING PLASTIC POLLUTION 24

4.1 Circular economy practices in the manufacturing stage 26

Product Design 27

Resource efficiency and Cleaner Production 31

4.2 Circular economy practices to reduce the plastic waste generated during transportation 38

4.3 Circular economy practices to reduce the single use plastic products passed on to consumers at points of sale in the service sector 39

4.4 Circular economy practices to reduce the plastic waste generated by consumers 49

4.5 Circular economy practices to increase recycling of single use plastic products discarded at the end of their useful lives 51

4.6 Final disposal 60

5 CONCLUDING REMARKS 64

REFERENCES 66

Glossary

***NOTE:** This glossary focuses on terms which are used in the context of a circular economy. It is primarily based on the glossary of terms developed by the Ellen Macarthur Foundation.[1] Where other sources are used, these are cited separately.*

Anaerobic digestion:

Microbial breakdown of organic matter in the absence of oxygen. In a circular economy, anaerobic digestion can be used to convert food waste and by-products, sewage sludge, and other biodegradable materials into digestates (or 'biosolids'), which can be used as soil enhancers, and biogas.

Biological cycle:

The processes – such as composting and anaerobic digestion – that together help to regenerate natural capital. The only materials suitable for these processes are those that can be safely returned to the biosphere.

Circular Economy:

A systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution. It is based on three principles, driven by design: eliminate waste and pollution, circulate products and materials (at their hig hest value), and regenerate nature. It is underpinned by a transition to renewable energy and materials.

The transition to a circular economy entails decoupling economic activity from the consumption of finite resources. This represents a systemic shift that builds long-term resilience, generates business and economic opportunities, and provides environmental and societal benefits.

Composting:

Microbial breakdown of organic matter in the presence of oxygen. In a circular economy, composting can be used to convert food waste and by-products and other biodegradable materials into compost, which can be used as a soil enhancer.

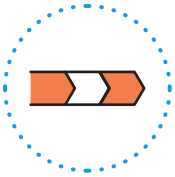
Durability:

The ability of a product, component or material to remain functional and relevant when used as intended. Durability often applies to the physical attributes of a product (its ability to resist damage and wear), though with some products durability can be technological (for example the ability of software to be upgraded many times), and it can be emotional (for example the ability of certain clothes to stay desirable over time).

Extended Producer Responsibility (EPR):[2]

An environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle. An EPR policy is characterised by:

1. the shifting of responsibility (physically and/or economically; fully or partially) upstream towards the producer and away from municipalities; and
2. the provision of incentives to producers to take into account environmental considerations when designing their products.



Linear Economy:

An economy in which finite resources are extracted to make products that are used – generally not to their full potential – and then thrown away ("take-make-waste"). It is a wasteful and polluting system that degrades natural systems.

Maintain:

Keep a product in its existing state of quality, functionally and/or cosmetically, to guard against failure or decline. It is a practice that retains the highest value of a product by extending its use period.

Non-virgin materials:

Materials that have been previously used. This includes: materials in products that have been reused, refurbished or repaired; components that have been remanufactured; materials that have been recycled. Also referred to as secondary materials.

Recyclability:

The ease with which a material can be recycled in practice and at scale.

With respect specifically to plastic packaging, packaging or a component thereof is recyclable if postconsumer collection, sorting and recycling is proven to work in practice and at scale. A package can be considered recyclable if its main packaging components, together representing more than 95% of the entire packaging weight, meet this requirement, and if the remaining minor components are compatible with the recycling process and do not hinder the recyclability of the main components.[3]

Recycle:

Transforming a product or component into its basic materials or substances and reprocessing them into new materials. Embedded energy and value are lost in the process. In a circular economy, recycling is the last resort action.

Refurbish:

Return a product to good working order. This can include repairing or replacing components, updating specifications, and improving cosmetic appearance.

Regenerative production:

Regenerative production provides food and materials in ways that support positive outcomes for nature, which include but are not limited to: healthy and stable soils, improved local biodiversity, improved air and water quality. In agriculture, regenerative production schools of thought include agroecology, agroforestry, and conservation agriculture.

Remanufacture:

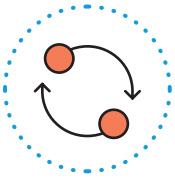
Re-engineer products and components to as-new condition, with the same, or improved, level of performance as a newly manufactured one. Remanufactured products or components are typically provided with a warranty that is equivalent to, or better than, that of the newly manufactured product.

Repair:

Operation by which a faulty or broken product or component is returned back to a usable state to fulfil its intended use.

Repairability:

The ease with which a product or component can be repaired.



Repurpose:

The process by which an object with one use value is transformed or redeployed as an object with an alternative use value.[4]

Resource Efficiency and Cleaner Production (RECP):[5]

The continuous application of preventive environmental strategies to processes, products and services in order to increase efficiency and reduce risks to humans and the environment. RECP addresses the three sustainability dimensions individually and synergistically: a) heightened economic performance through improved productive use of resources, b) environmental protection by conserving resources and minimising industry's impact on the natural environment, and c) social enhancement by providing jobs and protecting the wellbeing of workers and local communities.

Reuse:

The repeated use of a product or component for its intended purpose without significant modification. Small adjustments and cleaning of the component or product may be necessary to prepare them for the next use.

Reverse logistics:

Supply chains dedicated to the reverse flow of products and materials for the purpose of maintenance, repair, reuse, refurbishment, remanufacture, recycling, or regenerating natural systems.

Sharing:

The use of a product by multiple users. It is a practice that retains the highest value of a product by extending its use period.

Technical cycle:

The processes that products and materials flow through in order to maintain their highest possible value at all times. Materials suitable for these processes are those that are not consumed during use, such as metals, plastics and wood. In the technical cycle, the opportunities to maintain and generate value come through retaining the greatest proportion of the energy and labour embedded in the product. This is achieved, in order of value, by: maintaining, repairing, prolonging, sharing; reusing and redistributing; refurbishing and remanufacturing; and recycling.

Virgin materials:

Materials that have not yet been used in the economy. These include both finite materials (e.g., iron ore mined from the ground) and renewable resources (e.g., newly produced cotton).

01
Introduction

Plastics are versatile materials, being inexpensive, light, easily shaped and durable, which have brought immeasurable benefits to many areas of life. As a result, plastic products have seen a huge and rapid rise in production, from almost nothing in the early 1950s to a little over 400 million tonnes/year as of 2015[6], with no signs of abatement in the rate of growth: it has been estimated that under the Business As Usual scenario, an extra 26 billion tonnes of plastic products could be produced by 2050.[7]

Currently, some 36% of all plastic products are used in packaging. Another 16% are used in building and construction. A further 14% are used in textiles and 10% in consumer and institutional products. The remainder see use in transportation, electrical and electronic products, and a wide variety of other products.

Primarily made from fossil-fuels, plastic materials are valuable and embody our world's limited natural resources (in addition to oil, much energy, mostly non-renewable, and water). Yet this value is not reflected in their fate. Of the 8.3 billion tonnes of virgin plastics produced between 1950 and 2015, only 30% are still in use. The remaining 70%, or 5.8 billion tonnes, have become waste. Of these 5.8 billion tonnes, it is estimated that about 0.5 billion tonnes have been collected for recycling, but because of the poor quality of the waste and technical limitations in

1950-2015

8.3 bn

tonnes of virgin plastics produced.
Only 30% are still in use.

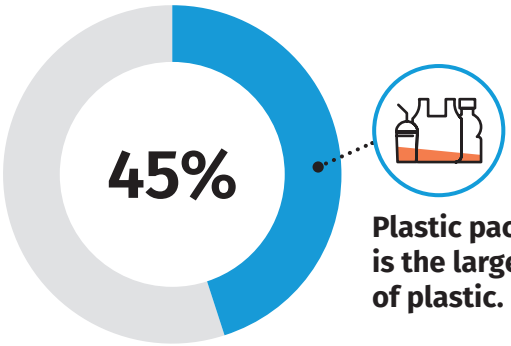
The remaining 70% have become waste.

by 2050

12 bn

tonnes will have been landfilled or dispersed in the natural environment.

the recycling technology only 0.1 billion tonnes, or a little under 2% of total plastic waste, has actually been recycled. Of the remainder, 14% (0.8 billion tonnes) has been incinerated and 84% (4.9 billion tonnes) has either been deposited in landfills and dumps or has been dispersed into the natural environment.[8] If current production and waste management trends continue, by 2050 roughly 8 billion tonnes of plastic waste will have been recycled, 12 billion tonnes incinerated and another 12 billion tonnes landfilled or dispersed in the natural environment.[9]



Plastic packaging is the largest use of plastic (almost 45% of plastic resin production is destined to its manufacture). Plastics are very effective as a material for packaging products due to their low weight, high strength, durability, and flexibility. Yet, with their short lifespan, commonly ending after only a single use, plastic packaging products put considerable pressure on waste collection, recovery and disposal systems. It has been estimated that 14% is collected for recycling, but only 2% is actually recycled into the same or similar quality applications, with another 8% recycled into lower quality uses that are generally not recyclable after use, and the remaining 4% lost as process losses. 14% of the waste plastic packaging is incinerated, possibly with energy recovery, 40% is landfilled, and 32% is dispersed into the environment.[10] Much of the latter make up the 9-14 million tons of plastic waste which it is estimated entered the oceans in 2016.[11] Many of the other single use and short-lived plastic products show the same environmental fate profile.

The concerns raised globally by the rapidly growing problem of plastic pollution have recently led to a decision to develop an international legally binding instrument (ILBI) to tackle plastic pollution, including in the marine environment. In 2022, the UN Environment Assembly (UNEA) adopted a Resolution in which it decided to convene an Intergovernmental Negotiating Committee (INC) with the task of developing the ILBI. The INC has met twice to date and will continue meeting until a text of the ILBI has been developed for submission to the UNEA for approval.

The objective of this paper is to contribute to the discussions of the INC, highlighting how resource efficiency and circular economy concepts can provide useful pathways forward in efforts to reduce plastic pollution, including in the marine environment. The paper focuses in particular on packaging and other single use plastic products, which make up the largest portion of this pollution.

02

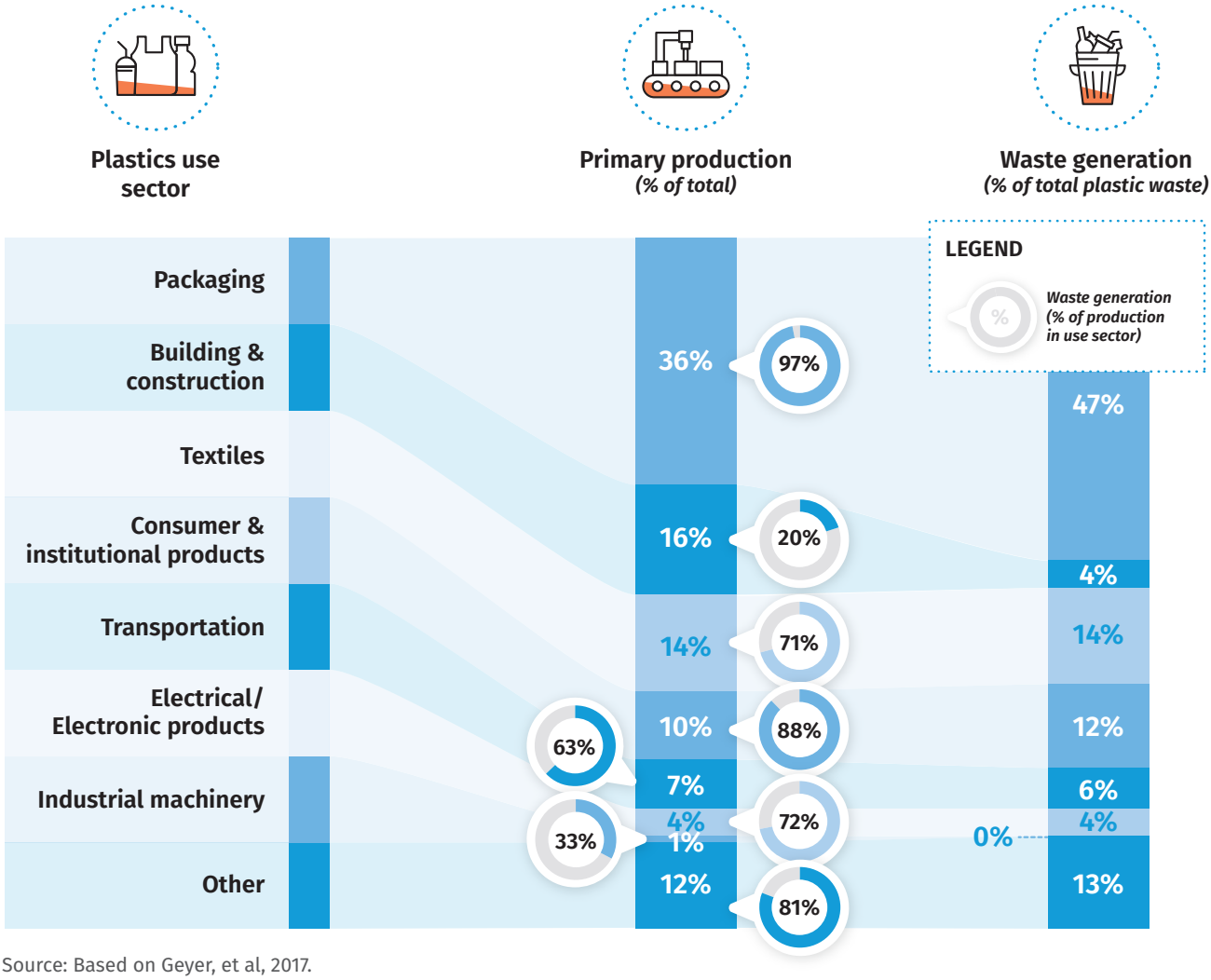
The source and fate of plastic packaging as well as other single use plastic products

2.1 Plastics production and waste generation

In 2015, global production of plastic products made from primary, or virgin, plastic resins and fibres was 407 million metric tons (Mt)[12] and is expected to double by 2030, and to double again by 2050. This figure does not include bio-based plastics, for which total production was about 4 Mt in 2015[13], approximately 1% of total annual production of fossil fuel-based plastics.

The manufacture of plastic products was globally dominated by four use sectors in 2015: packaging (146 Mt, 36%), building and construction (65 Mt, 16%), textiles (47 Mt, 14%) and consumer and institutional products (42 Mt, 10%).
In terms of waste generated as the proportion of annual production, packaging led with 97%, followed by 88% for consumer and institutional products. With respect to total annual plastic waste generated, packaging (47%), textiles (14%) and consumer and institutional products (12%) emerged as top contenders, see Figure 1. This is a reflection of their short to very short lifetimes: 1, 5, and 3 years on average, respectively. On the other hand, while building and construction used a good proportion of the plastics products manufactured, it was responsible for a substantially smaller proportion of the plastic waste generated, a result of these products' considerably longer lifetimes (35-40 years on average).

Figure 1: Importance of plastics use sectors in production and waste generation, 2015



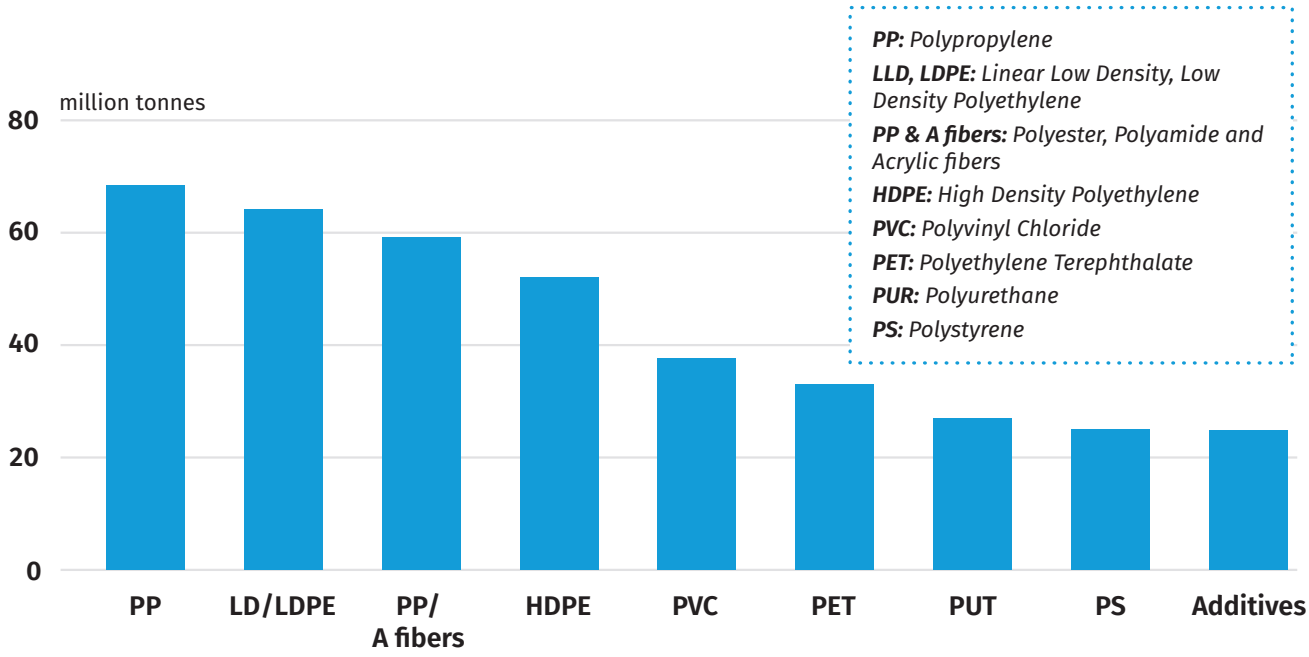
Source: Based on Geyer, et al, 2017.

Of the 8.3 billion tonnes of products manufactured with virgin plastics between 1950 and 2015, only 30% are still in use. The remaining 70%, or 5.8 billion tonnes, have become waste. Of these 5.8 billion tonnes, it is estimated that about 0.5 billion tonnes have been collected for recycling, but because of the poor quality of the waste and technical limitations in the recycling technology only 0.1 billion tonnes, or a little under 2% of total plastic waste, has actually been recycled. Of the remainder, 14% (0.8 billion tonnes) has been incinerated and 84% (4.9 billion tonnes) has either been deposited in landfills and dumps or has been dispersed into the natural environment.[14]

2.2 Most commonly used polymers in plastic packaging

A range of plastic polymers are produced. Figure 2 shows the levels of production of the most commonly used plastic resins and fibres (as well as the additives used in plastic products) in 2015.

Figure 2: ***Global primary plastic production (in million metric tons) by polymer type, 2015***



Source: Geyer et al., 2017, as reported in Our World in Data, https://ourworldindata.org/grapher/plastic-production-polymer

Overall, the largest application sector for plastic resins is packaging, with a share of almost 45% of total production. However, different plastic resins are used to differing degrees in the production of packaging products, as shown in Table 1. It is this mix of different plastics, along with the use of additives, which create challenges in the separation and recycling of packaging waste.

Table 1: ***Polymers used in packaging***

PLASTIC RESIN	% OF RESIN PRODUCTION FOR PACKAGING	PRODUCTION FOR PACKAGING, MT
LLD, LDPE	67.5%	43.6
PET	100%	32.6
HDPE	57.1%	30.0
PP	38.9%	26.5
PS	2.3%	7.4
PVC	7.7%	2.9
PUR	2.4%	0.6

Source: Geyer, et al, 2017.

These different plastic resins are also used for different types of packaging:

- LLDPE and LDPE is used in such products as plastic bags, trays, containers and food packaging films.
- HDPE is used in such products as milk bottles, freezer bags, shampoo bottles, and ice cream containers.
- Much of PET is used for the production of bottles, but it is also used for other products such as dispensing containers for cleaning fluids and biscuit trays.
- PP is used in such uses as microwave dishes, ice cream tubs, potato chip bags, and bottle caps.
- PS is commonly used for disposable cutlery, in food packaging such as yogurt containers, lids, trays, and bottles. In its expanded form it is used for disposable hot drink cups, and filling for packaging in the form of blocks or beads.
- PVC is little used in packaging; its main used is as food packaging, to ensure easy, gas-tight packaging for fresh fruits, vegetables and meat, as well as in stretch film.
- As Table 1 indicates, PUR is hardly used at all in packaging.

2.3 The use of additives in plastic packaging

The properties of all plastic products are usually enhanced by a variety of additives to an average amount of 7% by weight. Packaging is no exception. The three most common additives to plastic packaging, in order of importance, are oxygen scavengers, UV stabilisers, and antistatic additives. Oxygen scavengers help to extend product life and improve product appearance by absorbing and removing any oxygen left in the closed packaged product. In recent years, innovations have enabled oxygen scavengers to be impregnated into laminates, cards, films, bottles, plastic lids and closures. UV or light stabilisers protect the package and their contents from the damaging effect of ultraviolet and infrared radiation from sunlight. Antistatic additives eliminate or lessen the build-up of static electricity in the packaging.

A number of additives used in plastic products in general can have hazardous characteristics.[15] While such additives are typically selected in a way that their undesired characteristics do not impact during the intended use phase, they can pose serious issues at the end of life. In addition, the difficulties of separating out additives pose a serious impediment to mechanical recycling, which is currently the most prevalent form of plastic recycling (see below Section 4.5).

2.4 The flow of plastic packaging and other single use plastic products from the economy into the environment

Plastic packaging as well as other single use plastic products escape from land-based activities in the economy and into the environment mainly because they are mismanaged once they become waste:

- They are deposited in non-sanitary landfills or dumps, where the proper protection systems are not in place, so the wastes, particularly the lighter forms of packaging wastes, can be blown or washed away into the surrounding environment;
- They are inefficiently collected or are not collected at all, particularly in rural areas where waste collection and management systems are missing, and they simply get blown or washed away into the environment directly at the point of use;
- These routes into the environment are enhanced because of the lack of segregation at source in many localities, meaning that plastic wastes are mixed in with all other types of waste, making any form of waste management other than landfilling or dumping extremely difficult if not impossible.

Once these wastes have escaped into the terrestrial environment, they can enter waterways, either directly or indirectly via sewage systems, and from there can then be carried into the seas and oceans. Alternatively, if landfills and dumps are sufficiently close to coasts, the wastes can be blown or washed directly into seas or oceans.

03
Circular Economy – an Introduction

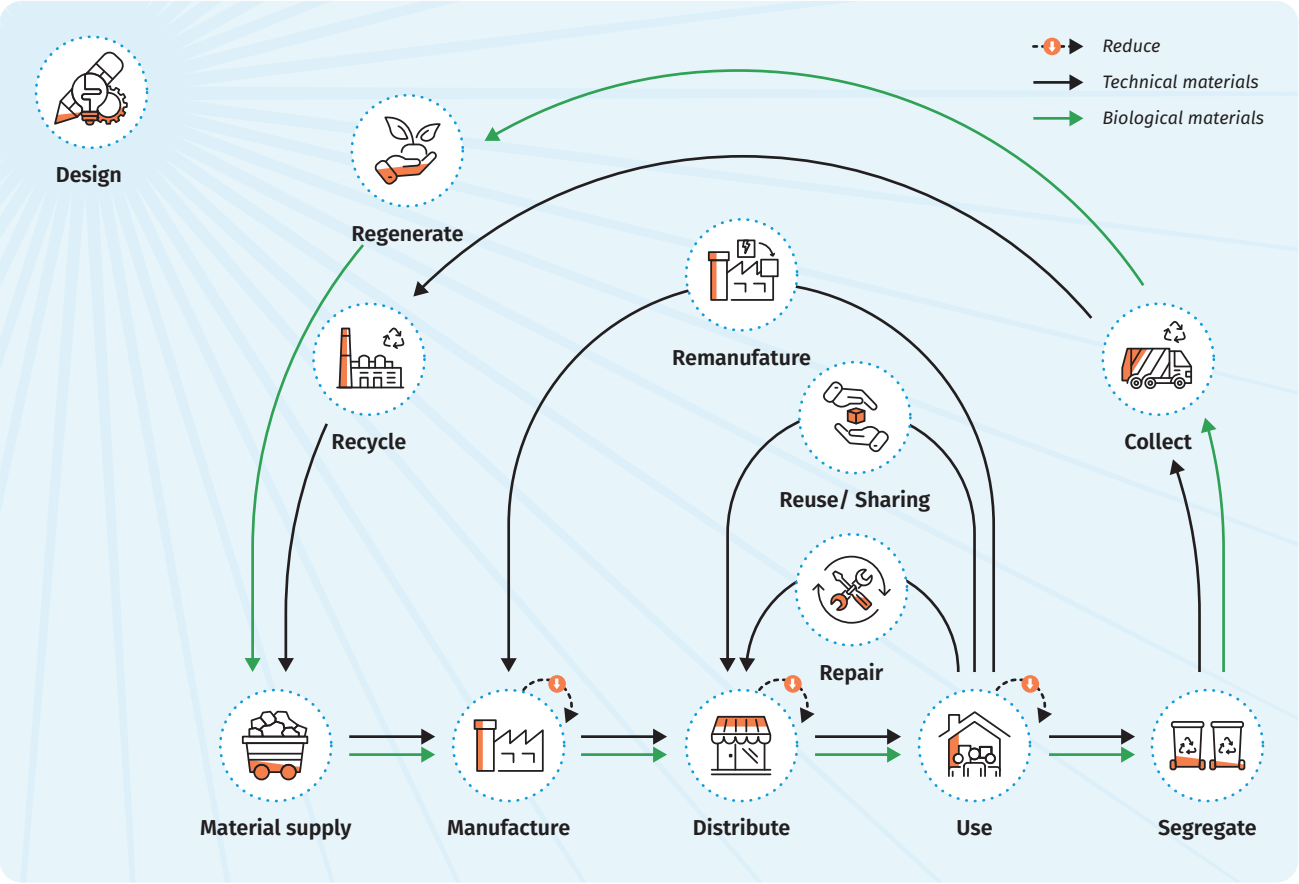
Prior to describing how the transition to a circular economy can lessen the amount of plastic packaging and other single use plastic products escaping into the environment and polluting both the terrestrial as well as the marine environment, it will be helpful to review the basic principles underlying a circular economy and how those principles apply to these kinds of products.

A circular economy has been defined as "a systems solution framework … based on three principles, driven by design: eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature".[16]

It is a new way of creating value, by extending product lifetimes and relocating waste from the end of the value chain to the beginning – in effect, using products and their resources more efficiently and for a longer time by using them more than once. Systemic innovation is at the core of circular economy practices.

Circular economy practices ensure that products and the resources which make them up are put to productive and efficient use within the economy over and over again. The retained value in products and the resources which they contain thereby create business opportunities, income, and jobs many times and not only once as in today's linear economies, where products usually end up in landfills at the end of their one and only life. Figure 3 shows the various circular economy practices which can be adopted.

Figure 3: ***Importance of plastics use sectors in production and waste generation, 2015***



A circular economy starts at the product design stage by the design team thinking in a forward-looking way about how the product and its component parts could be more easily maintained, repaired, reused, remanufactured and recycled so that both the product and its constituent materials have a longer, more productive lifetime. Product designers also look backward, by giving consideration to how recycled raw materials can replace virgin raw materials in the production of new products and their component parts.

During the manufacture of products and their component parts, manufacturers will adopt resource efficiency and cleaner production (RECP) practices which reduce the overall environmental footprint of manufacture by reducing inefficiencies in material and energy use as well as the amount of GHG emissions, pollution and waste which are generated. Actors in distribution chains will do the same, with transporters reducing their environmental footprint during the transport of products to wholesalers and retailers, and wholesalers and retailers reducing the environmental footprint associated with their sales to consumers.

For their part, consumers will adopt a number of circular economy practices.

- At the point of sale, they can make a number of decisions. They can choose to only purchase products when they really need them. They can decide to purchase the services of products rather than the products themselves through rental, leasing or sharing arrangements. They can choose to purchase products which are durable and highly efficient. They can encourage the reuse of products, thus extending the useful lives of products, by choosing to purchase second-hand products rather than new ones.
- During use itself, they can adopt a number of practices. They can use and consume their products efficiently and in a manner that minimises GHG emissions, pollution and waste. They can maintain their products according to the guidance given by manufacturers. They can choose to have their products repaired when broken rather than throw them away and purchase a new product.
- Finally, once the products have reached the end of their useful lives, there are a number of practices which they can adopt. They can place the products they no longer need but still work into the second-hand market. They can send those products which can be remanufactured to remanufacturers (or to refurbishers if they can be refurbished). They will choose to properly segregate the remainder of their discarded products so that they can be properly recycled.

In the final cycles, remanufacturers will remanufacture products as efficiently as possible, ensuring that any parts which they will no longer use are recycled properly. For their part, recyclers will extract the constituent materials from the discarded products they receive in the most efficient and least polluting way, ensuring at the same time a stream of high-quality recovered material which can go back to a new product with as high a value as the original product from which it came. In the case of waste biological materials, recyclers will extract the constituent nutrients (nitrogen, phosphorus, potassium, other nutrients) as well as carbon from these materials, using industrial processes such as composting and anaerobic digestion, with the nutrients going back to the land to support regenerative primary production.

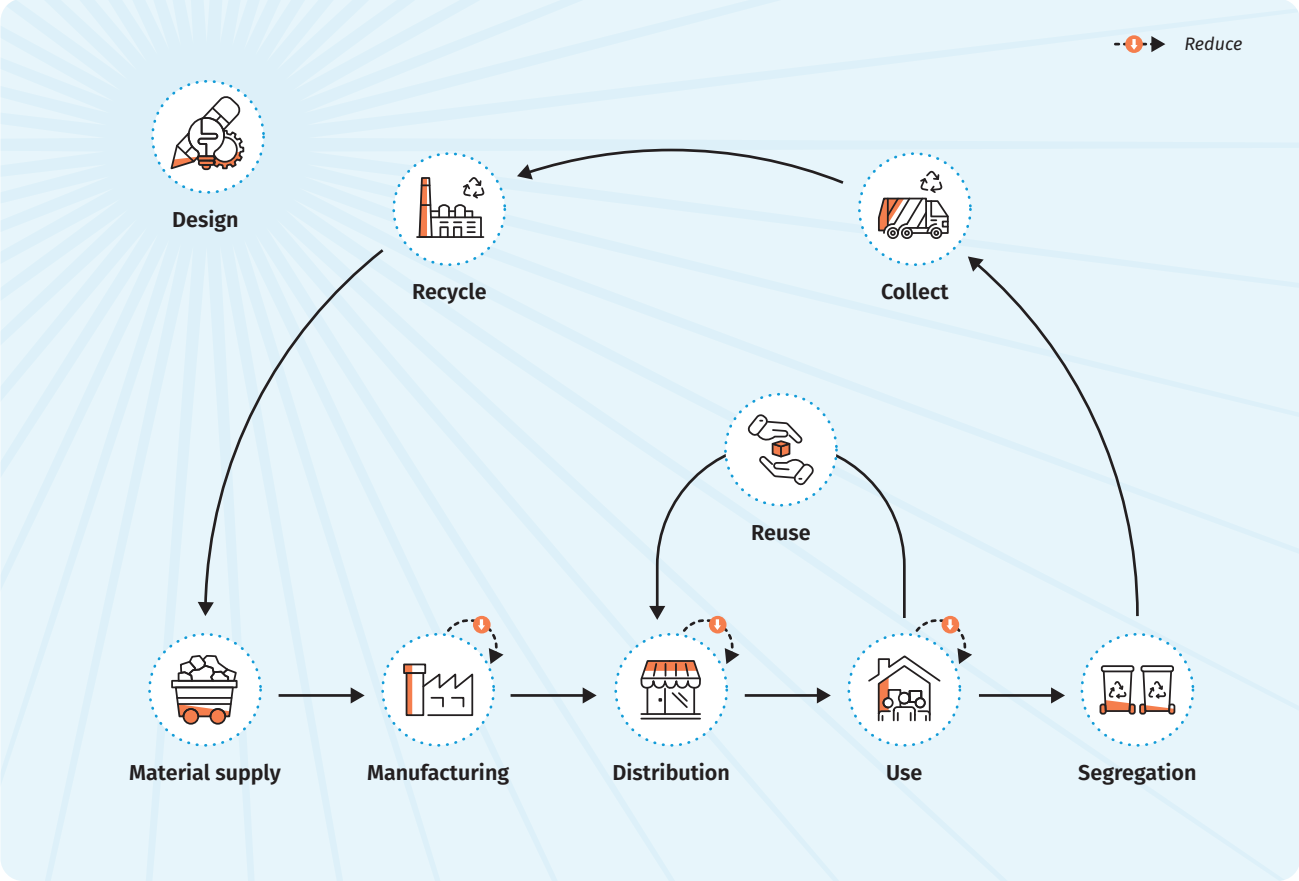
Many of these circular economy practices are already in use to a greater or lesser degree for long-lived products: from durable consumer goods such as washing machines and furniture to high quality shoes or clothes that do not fall out of fashion very quickly or fall apart after a few uses, to industrial, agricultural, road, marine and air transport, electrical, electronic and healthcare equipment, to the buildings that we live and work in. A good example is automobiles. During their manufacture, the factories can adopt RECP practices to reduce manufacturing inefficiencies and waste. So, too, can the actors in the distribution chains for automobiles. At the point of sale, consumers can decide to purchase their own new automobile, or a used automobile, or not to own an automobile at all but take part in sharing or leasing schemes for automobiles. During the use of automobiles, their owners can make sure that they are used efficiently. They can also ensure that they are properly maintained and repaired (they can be assisted in this by designers ensuring that the automobiles' design allows for easy maintenance and repair). If owners no longer need their automobiles but they are still functioning, they can ensure that they enter the second-hand market to continue their useful lives. At the end of automobiles' lives, their owners can ensure that they go to remanufacturing. For maximum efficiency, this will require the distribution sector to establish reverse logistics systems to bring old automobiles to remanufacturing facilities, where their engines and hydraulics – some of the most valuable of an automobile's components – are remanufactured to a quality level equivalent to that of new automobile engines and hydraulics (again, designers can ensure that the design of automobiles allows for the easy remanufacturing of these components). After remanufacturing, engines and hydraulics can start a new life in another automobile. All other parts of old automobiles can instead be extracted for reuse as spare parts in other automobiles or even as parts in new automobiles. Any remaining components of old automobiles which cannot be reused can be directed to recycling facilities where the constituent steel and other materials can be recycled into making parts for new automobiles or other products, thus avoiding the inefficiencies and environmental externalities linked to the mining and processing of virgin materials.

With plastics, on the other hand, the picture is mixed. Some plastic products such as those used in buildings (e.g., PVC windows, doors and water pipes, outside panelling), automobiles (e.g., many parts under the hood, bumpers outside and in the passenger cabin, including seat textiles), healthcare (plastic parts of magnetic resonance imaging (MRI) devices), long-lived consumer goods (e.g., plastic garden chairs and tables, plastic shelves in refrigerators, the seats in office furniture) are made to last. With respect to circular economy practices, these long-lasting, durable plastic products and their parts and components are similar to other durable consumer goods and many of the circular economy practices shown in figure 3 can be used with them: they can be repaired, reused, refurbished and recycled depending on the type of plastic polymers used to make them.

Other plastic products have short to very short lifetimes and are discarded almost immediately in today's linear economies. This is particularly the case for plastic packaging (e.g., plastic beverage bottles, cling wrap, candy wrappers, containers for fast food, cleaning and personal care products), as well as other single-use plastic products (e.g., cutlery, plates, straws, shopping bags). Also in this category are short-lived consumer goods containing plastic such as inexpensive clothing or trainers that go out of

fashion and favour rapidly or fall apart quickly through normal wear and tear. Other examples are plastic products that cannot stand up to the forces of nature for very long (e.g., fishing gear that gets lost in open seas such as plastic fishing nets, ropes, floats, oyster spacers, baskets, crates, traps). For these products, the circular economy practices which can be adopted are a smaller set than those shown in Figure 3. Figure 4 shows the set of practices for plastic packaging and other single-use plastic products in particular.

***Figure 4:** Circular Economy Practices for plastic packaging and other single use plastic products*



Nevertheless, even in these cases we can use these circular economy practices to extract much more value of the value embedded in these short-lived plastic products than we do now. We can start from product design so that these types of plastic products and their constituent materials are more durable, are made from renewable materials rather than non-renewable fossil fuels, are non-toxic, are easily recyclable. We can also make systemic innovations, designing and using alternatives which are long-lived. We can then ensure that plastic leakage into the environment is prevented during production and distribution, as well as during product use and service delivery, through greater efficiency practices. Finally, we can maximise the amounts of discarded products going to recycling as well as maximise the amounts of recovered plastic by innovating on the technologies used for recycling. How we do all this is the topic of the chapter that follows.

04

Circular economy practices for addressing the challenge of reducing plastic pollution

Plastic packaging and other single use plastic products make up a considerable portion of all plastic pollution, including in the marine environment. Their main characteristic is their very short life spans, driven by the fact that they have been designed to have a single use before they are discarded.

Like all packaging, **plastic packaging** protects the product it encloses from external influences during transport and distribution, including from theft at the retailer's display. It is also used to promote the brand and instil trust in the consumer about the product. The packaging may also carry information about the product it contains. In some societies the aesthetics of packaging is a value in itself. The packaging's purchaser is a business entity, mostly producers of food, beverages, shampoo, toothpaste, detergent and similar products, aimed at the consumer market.

When the end user has consumed the meat, the vegetables, the candy bar, the toothpaste, the shampoo, the packaging has completed its function and, given that most plastic packaging is used only once, it immediately loses all of its value to the consumer and is discarded.[17]

Other **single use plastic consumer products** such as plastic bags, utensils (forks, knives, spoons, cups, straws, etc.), as well as sanitary and personal care products, similarly have very short life spans. They are designed to be used once, after which the consumer is expected to discard them.

This chapter will follow these plastic products through the different stages their life cycle. These consist of the following:

STAGE 1:

the manufacture of the products and, in the case of plastic packaging, of the goods which will be encased in plastic packaging.

- Note that the life cycle of the materials making up the products (the monomers of the plastics and, upstream of that, the raw materials from which the monomers were derived; the various chemicals and their upstream starting raw materials in the case of the additives) has already started upstream of this stage. However, since, in a circular economy, the principle is to have future packaging and other single use plastic products made from recycled plastics, these currently earlier stages in the materials' life-cycle will not be covered here because they are part of these products' life cycle in a linear economy. Nevertheless, it is good to remember that some of the circular economy practices discussed in this report – notably resource efficiency and cleaner production – are equally applicable to these earlier stages in the currently linear life cycle of the underlying materials.
- Should chemical recycling[18] of plastics become an important route in the recycling of plastics in the future, then the operations involved in the chemical recycling can be included in this type of analysis; these are very similar to the current operations for manufacture of the monomers and the plastic resins.
- Note, too, that in any event the upstream manufacturers of the plastic resins will get involved to some degree in Stage 1, since the physical properties of the resins used can influence the (re)design of the plastic products of concern here.
- In a good number of countries, goods that are already packaged are imported, in which case this stage will not be relevant; both the manufacture of the packaging and the packaging of the goods will take place in the exporting countries. Importing companies will be involved in Stage 2, as part of the distribution networks.

STAGE 2:

the distribution of the products from their point of manufacture (or importation) to the point of sales.

- This stage is composed of two quite different activities, the transportation of packaged goods, and their sale in supermarkets, shops, or other retailers. As a consequence, the circular economy practices which can be adopted are relatively different. Therefore, the two activities will be discussed in separate sections.
- Note that transportation is to be found in all of the other stages. With respect to Stage 1, recovered plastic is transported from the recycling facilities to the manufacturers of the plastic products, and plastic packaging is transported to the sites where they will be used to package goods. In Stage 3, packaged goods and single use plastic goods can be delivered to the consumer by van (or the consumers themselves transport the goods home in their car). As for Stage 4, the discarded packaging and other single use products are transported to the recycling facilities, and the plastic which these facilities recover is transported to manufacturers of plastic products. The circular economy principles outlined for transportation in stage 2 are equally applicable to these other phases of transportation, except for the transportation of wastes, which have special characteristics; these will be discussed under Stage 4.[19]

STAGE 3:

the use of the products.

While many of the consumers of packaged goods and single use plastic products are households, it is important to remember that consumers can also be commercial, institutional, or even manufacturing entities. For instance, restaurants and canteens will purchase many packaged food products as well as single use plastic products to use in their food services, coffee shops will purchase many single use plastic products, hotels and other entities with meeting facilities will purchase bottled water to offer at the meetings, and so on.

STAGE 4:

the recycling of the products once they come to the end of their useful lives.

For each stage, the circular economy practices which can be usefully adopted will be examined; examples will be provided where such practices are already being employed; and the possible and already existing regulatory frameworks will be identified aiming to facilitate the uptake of such practices.

The examples given are not meant as an endorsement of any particular manufacturer or practice, but only as an illustration of the current technical possibilities and trends. Moreover, the authors were not in the position to verify the different claims made by manufacturers or others about the performance characteristics of products and processes.

4.1 Circular economy practices in the manufacturing stage

Two critical circular economy practices come into play at the manufacturing stage:

- The design of the products;
- The adoption of more efficient manufacturing processes.

Since these are very different from each other, they will be considered separately.

4.1.1. PRODUCT DESIGN

Preface

A key circular economy practice to be undertaken in the manufacturing stage is the design of the product (or its redesign, if it is already on the market). Design for plastic packaging and other single use plastic consumer products (or their alternatives) is critical in determining what kind of circular economy practices could be used in later stages of their lifecycle and how well these practices could work. Design decisions are intimately linked to the business model which the company will adopt with respect to circularising its products.

Various actors are involved in the (re)design of plastic packaging and other single use plastic consumer products. With respect to plastic packaging, design decisions can be made at two steps in the manufacturing stage.

- They can be made by the manufacturers of the plastic packaging itself. They will often do this in collaboration with producers of the plastic resin, because the latter are very familiar with the properties of their plastics. In these cases, the design decisions will normally take it as a given that plastics will continue to be used in the packaging product – unless the manufacturers of the packaging decide to radically change their business model and start making non-plastic packaging.
- Alternatively, the design decisions can be made by the companies using the plastic packaging to package the products they make. In this case, the most common design decision is to move away from packaging made with plastics produced from fossil fuels to packaging made with alternative materials. Usually, the companies will work with the manufacturers of these alternative types of packaging. These decisions could be driven by signals they receive from their clients in the retail sector, who are looking for products with circular packaging.

With respect to other single use plastic consumer products, the situation is slightly simpler. Product (re)design decisions are taken by the manufacturers of the product, although here too their (re)design decisions could be driven by signals they receive from their clients in the retail sector who are looking for circular products.

Circular economy practices to circularise plastic packaging and other single use plastic consumer products through design

With respect to **plastic packaging**, different design questions would need to be considered depending on which step in the manufacturing stage is being considered.

The manufacturers of plastic packaging would need to consider the following design decisions:

- Is it possible to reduce the amount of plastic used in the packaging (light-weighting)?
- Is it possible to use recycled plastic in the packaging?
- Can this packaging be made from one polymer rather than different polymers, e.g., can caps be made from the same polymer as the bottles they close?
- Is it possible to eliminate the use of hazardous chemicals as additives? Not only could these chemicals impact the health of consumers, they could also make the packaging unsuitable for mechanical recycling, hence requiring chemical recycling to extract the useful polymers or only allowing their burning in waste-to-energy facilities;[20]
- Is there a mechanism to manage the plastic packaging after its use to maintain some economic value?

The companies using the plastic packaging to package other products would need to consider the following design questions:

- Is it possible to replace packaging made with plastics produced from fossil fuel with packaging using an alternative material (e.g., bio-plastic or other renewable material[21], or a more easily recyclable material) that offers similar functionality? Any alternative packaging should both be likely to reduce the amount of plastic which is discarded and, ideally, have no other (significant) environmental disadvantages;
- Can the packaging be replaced with reusable and more durable plastic packaging to render it suitable for multiple uses and a longer lifetime? Could this also result in a new business model?

- Is it possible to eliminate thin films? Eliminate multilayer packaging or use an easier to recycle multilayer packaging? Eliminate certain colours used in plastic? All these are challenging to deal with in mechanical recycling and are likely to lead to the recovered plastic having a low value;
- Is it possible to reduce if not totally eliminate the packaging (plastic or otherwise) used for the product?

In the case of other **single use plastic consumer products**, the manufacturers of these products should consider the following design questions:

- Is it possible to reduce the amount of plastic used in these products (light-weighting)?
- Can the fossil-fuel-based plastics used in these products be replaced with bio-based plastics or with other materials altogether, subject to the latter having more favourable lifecycle impacts compared to the former?
- Is it possible to use no/fewer and less harmful additives in the plastic used in these products?
- Is it possible to use recycled plastics in these products?

Examples

Design for biodegradable packaging and single-use products

Kaneka of Japan has launched Green Planet™, the brand name of PHBH (poly(3-hydroxybutyrate-co-3-hydroxyhexanoate))[22], a 100% bio-based, biodegradable material which is a polyester made through microbial fermentation. PHBH has similar properties to polyethylene (PE) and polypropylene (PP) and is an alternative to these fossil-based polymers. It has been certified for use in food packaging and as being compostable (home composting) and biodegradable in the marine environment.

Californian **Newlight Technologies** produces AirCarbon™, a brand name of polyhydroxybutyrate (PHB), by running seawater containing dissolved air and carbon dioxide through a bioreactor which houses marine microorganisms. PHB is a naturally occurring polymer that is biodegradable. It is being used to manufacture home-compostable straws, compostable cutlery, as well as dishwasher-safe premium cutlery.[23]

Nihon-Cornstarch[24] has a biodegradable polymer, polylactic acid (PLA), on the market that is suitable for making agricultural mulch films, but also ball point pens and paints.

Sulapac, a Finnish company, produces a compostable and biodegradable material made from the wood industry's side streams and plant-based binders. The company has joined forces with various other companies to make packaging for them and more recently to make biodegradable straws which can be used for up to 24 hours without getting soggy.[25]

Evoware in Indonesia uses seaweed for making single-use food sachets and wrappings[26] that, at the end, can be dissolved or eaten. The raw material, seaweed, is used without additives. The same company has also come up with a material from the South Asia fig tree that holds liquid and can be used for personal care products and applications in medical supplies such as hygienic encasements for medical instruments.

Full Cycle Bioplastics, Elk Packaging, and **Associated Labels and Packaging** have all created bio-based compostable plastics made from organic waste combined with cellulose-based materials made from plant matter, as a replacement for multilayer packaging for food and other consumer products.[27]

Saathi is India's first biodegradable sanitary pad made from banana fibres with zero chemicals[28] that is also affordable for low-income women; in addition, the materials are sourced locally, reducing environmental impacts from transportation.

The German company **Tecnaro GmbH** produces a material called Liquid Wood, a biodegradable material, combining natural wood fibres with lignin, a by-product of the pulp and paper industry. Liquid wood has properties of plastic in terms of design and manufacturing, is highly durable, and withstands combined tensile and compressive loads. In addition to use as packaging, Liquid Wood can be used in various household items.[29]

Design for less material use

Plastic products are becoming less material intensive. According to a report by BVK[30], the weight of a yogurt cap has halved since the 1970s, and the average weight of a plastic bag in Germany has dropped by nearly one third from ten years ago.

Design for easier recycling

Multi-layer plastic products are challenging for recycling, yet innovations are showing a possible way forward.

Aronax Technologies Spain,[31] a winner of the Circular Materials Challenge,[32] provides an alternative concept to multilayer packaging by using a magnetic additive, which makes it easier to identify and separate layers of packaging during recycling. The particles, which play a role similar to the aluminium coating used in multilayer materials today, can be recovered and reused. This technology can be used to replace multilayer packaging for toothpaste tubes, food and drink containers.

The **University of Pittsburgh** has used nanotechnology to create multilayer food packaging from a single polymer, namely, polyethylene[33], combining it in layers with different properties. The material replaces multilayer packaging containing PET, polyethylene and aluminium. The new technology enables easy re-processing of the materials without separation steps.

The mixing of different plastic polymers in the same product also poses challenges for recycling. However, redesign is helping.

In Israel, UNIDO brokered a partnership between a number of local subsidiaries of the global brands **Danone** and **Nestlé**, **TMIR** (operator of the country's EPR scheme and owner of its waste sorting plant), and several actors in the value chains. The objective was to redesign the packaging used for food products (yoghurt/salads) to find a plastic with which to make sleeves to substitute the current PETG sleeves, which would allow the PP packaging to be properly detected by the optical sorting system at the waste sorting station and diverted to proper recycling. Sleeves made from PO were found to satisfy the requirements. The local subsidiaries are currently at different stage of now bringing their products using the new sleeves to the market, and one is considering the use of PO sleeves on other of its products.[34]

Design for use of recycled plastic

New World Recycling in South America is producing bottles using recycled plastic PET, for one of the world's largest soft drink companies. The company produces the recycled PET using a food-contact compliant process. As a result, around 300 million PET bottles a year are no longer discarded, but are recycled in a closed-loop process (bottle-to-bottle) back into valuable consumer beverage containers.[35]

Policy responses

Key options in the circular (re)design of plastic packaging and other single use plastic consumer products will be the use of alternative materials (recycled plastic, or biodegradable and compostable plastics, or other non-plastic alternatives), or the use of alternative products altogether.

On the supply side, ***government support for innovations and start-ups*** will be critical for the development of alternative materials and products. If governments already have programmes which support incubation and similar efforts, they can use these to focus on supporting new businesses which are developing alternatives to plastic packaging and other single use plastic products. Alternatively, they can create new incubation programmes for this purpose. One successful, but small-scale, example is UNIDO's Global Cleantech Innovation Programme (GCIP), supported by the Global Environment Facility (GEF), which is aimed at SMEs. This global multi-stakeholder partnership leverages the power of innovation and entrepreneurship to address resource and energy efficiency challenges. However, to create sufficient impact on this particular issue, innovation support programmes need to be on a larger scale and receive support for a longer timeframe.

Governments can also use their existing programmes which ***promote R&D*** to support stakeholders searching for new design solutions in this space. Governments can also help businesses cross the so-called "valley of death" between the R&D and start-up phase and full-scale operation, by offering them access to government-funded demonstration programmes and low-interest loans or loan guarantee schemes. Where governments have National Innovation Strategies, they should ensure that these strategies cover the issue of finding solutions to plastic pollution, including in the marine environment, by plastic packaging and other single use plastic consumer products.

Governments can also help to ***grow the demand for alternative materials and products*** in a number of ways. In their public procurement programmes, they can set as one of the criteria to be met that any single-use products, or the packaging of any packaged products, which they purchase are made either with recycled plastic or with biodegradable or compostable plastic, or with other alternative material. With respect to single-use products, they can reject such products and require instead that they are multi-use. Governments also need to put in place the necessary standards (along with the requisite certification systems) to build the market's trust in the efficacy and viability of the alternative

materials and products. Governments can also use fiscal incentives (e.g., removing subsidies on the virgin raw materials used to make plastic, taxing these raw materials, reducing the tax burden on alternative materials and products) to reduce the cost of the alternatives with respect to the plastic currently used.

4.1.2. RESOURCE EFFICIENCY AND CLEANER PRODUCTION

Preface

Irrespective of the design decisions which have been taken, the factories involved in the value chain of plastic packaging and other single use plastic consumer products can take steps to reduce, if not eliminate, the plastic wastes which they generate in their manufacturing operations. These wastes can be generated in a number of ways.[36]

- Poor handling of plastic pellets:
  - Plastic pellets are the most common raw material for the manufacture of all plastic products. These pellets can be lost at all steps of the supply chain: at the plastics manufacturers, during their transportation to factories making the plastic products, and finally during the manufacture of the products. Due to their small size (2-5 mm), they easily escape from waste management systems and get washed into sewers or waterbodies, ending up as marine litter.[37]
- During the manufacture of plastic packaging and other single use plastic consumer products:
  - Various steps in the manufacture of plastic products generate waste: during start-up of continuous operations, when there are process disruptions, excess plastic trimmed off products, etc.. More modern types of equipment allow for the reuse of these wastes. Where this is not done, or where the equipment is too old, waste plastic is generated;
  - There can be improper management of stocks in the factory's stores, so that either incoming plastic raw materials or outgoing plastic products are spoiled and become waste.
- During the manufacture of products where the final step is to insert the product into plastic packaging:
  - There can be improper handling and processing of the packaging, leading to some packaging being spoiled and becoming waste;
  - There can be improper management of stocks in the factory's stores, so that the incoming plastic packaging is spoiled and has to be discarded, as can outgoing product (together with its packaging).
- In all productive sectors where raw materials, components, and other inputs are received in plastic packaging:
  - When those inputs get fed into the manufacturing operations, the plastic packaging will be removed and – unless it is designed to be reused – it will be discarded.

In all cases, if the plastic waste streams are poorly managed, they can escape into the environment and become land-based or marine litter.

Circular economy practices to reduce single use plastic waste generated during manufacture

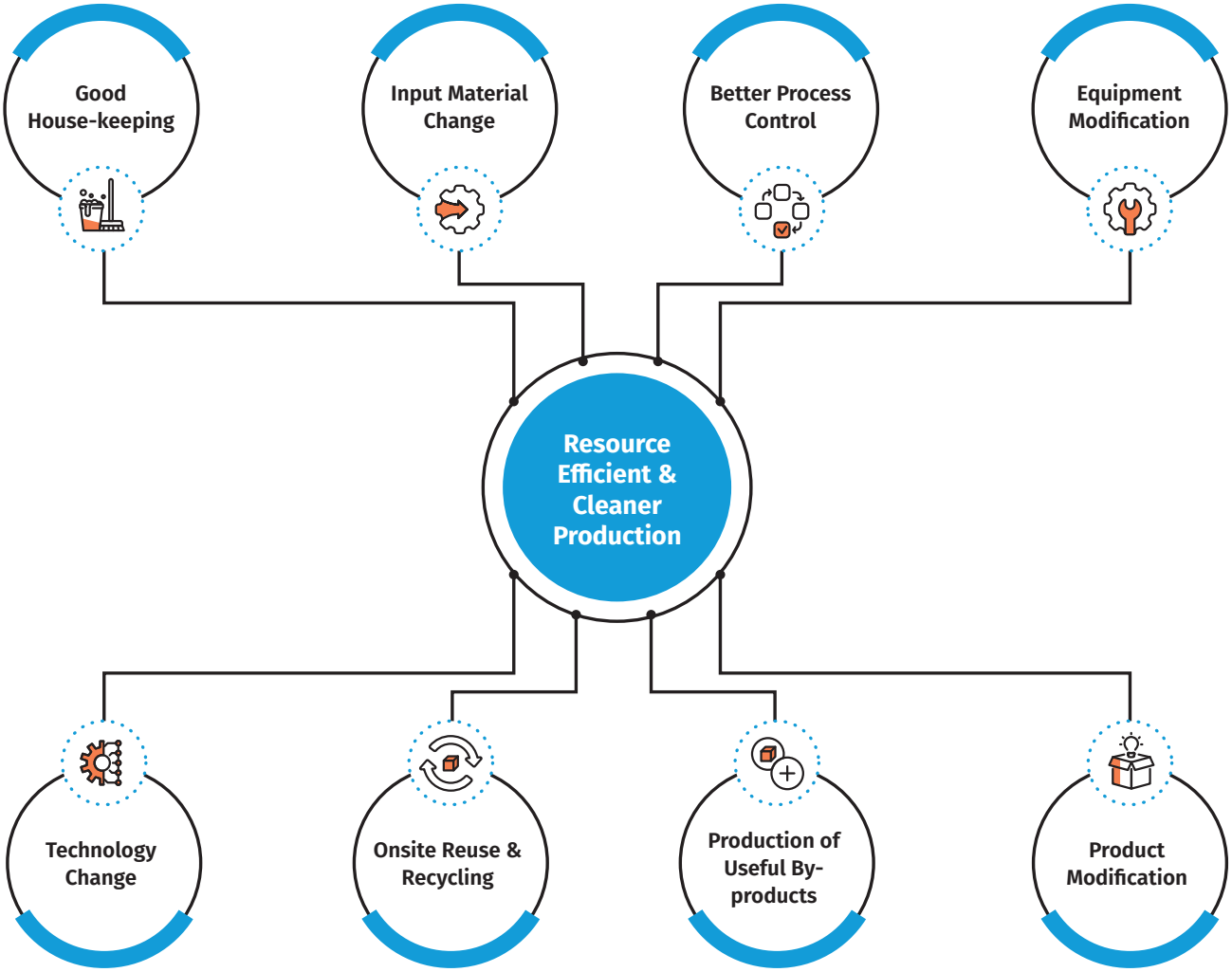
The waste generation described above can be reduced, if not eliminated, using the Resource Efficient and Cleaner Production (RECP) methodology. RECP applies preventive technologies, techniques, and practices, as well as total productivity management, to processes and products in the manufacturing and other productive sectors, with the triple aims of increasing efficiency and improving resource productivity, reducing environmental impacts, and fostering human health and wellbeing. In practice, RECP is always a win-win strategy for the factories which adopt it. It will improve their financial bottom line (by reducing their costs). It will also reduce their environmental impacts (by reducing their consumption of resources and reducing their GHG emissions, pollution and waste). Finally, it will reduce their impacts on human health (by reducing the exposure of their workers and/or their local communities to toxic and hazardous substances) and/or it will improve workplace conditions.[38]

More broadly, RECP makes good business sense. In addition to the cost savings just mentioned, there are productivity enhancements through the reduction of non-product outputs (i.e., waste, emissions, discharges). There are improvements in product quality from better controlled processes. There is greater organisational efficiency and effectiveness derived from greater staff motivation and better business processes. Finally, the adoption of RECP by a company supports its Social License-to-Operate, i.e., it helps in ensuring a greater acceptance by government, the local community, and the markets of the company's business practices and operating procedures.

Over the years, the application of the RECP methodology has shown convincing results in multiple manufacturing sectors such as food processing, building materials, textiles and chemicals, across both the developed and the developing world. While the RECP methodology was developed for use in the manufacturing sector, it can be equally well applied in all productive sectors.

RECP is operationalised through the deployment of an assessment process through which sources of wastage and its causes are identified, options for the reduction of this wastage are developed, and those options are subjected to economic, technical, and environmental assessments. The options which come out best in the assessments are implemented. The types of possible options, which are a variety of managerial, technical and operational measures, are shown in Figure 5.

Figure 5: ***RECP methods***



The RECP methodology has a high degree of relevance for actors along the plastics value chain. Processes of particular relevance are extrusion (used for manufacturing films and sheets), blow moulding (used for the production of bottles, containers, toys and houseware), and injection moulding (used for the production of packaging, bottle caps, toys, combs). Companies can and often do take numerous measures, subject to the type of operations they run, to eliminate loss of raw materials, while also preventing defects in products. Often, these measures include the installation of additional quality monitoring systems. For certain processes such as injection moulding, production waste can be reintroduced into the production process. Table 2 gives additional examples.

*Table 2: **Possible RECP options for minimising plastic waste in manufacturing***[39]

RECP PRACTICE	DESCRIPTION	EXAMPLES
1 Good Housekeeping 	Maintain a clean, organised and productive ("neat") workplace to eliminate avoidable wastage.	• Avoid mix-ups in material labelling, especially for additives. • Make sure that no plastic waste is brought in during material delivery. • Seal waste containers to avoid spills during transport. • Prevent mixing waste from the production process with other kinds of waste. • Properly maintain equipment to prevent plastic material losses during breakdowns.
2 Input Material Change 	Choose inputs that are efficient, effective and/or pose minimum harm to the environment and human health.	Change to more recyclable or biodegradable and compostable inputs.
3 Better Process Control 	Monitor and control processes and equipment so that they always run at highest efficiency and with lowest wastage.	Establish Standard Operating Procedures (SOPs) and ensure that they are followed.

4 Equipment Modification 	Make existing equipment more efficient and less wasteful.	Depends on the type of plastic production.
5 Technology Change 	Change over to new technology that is more efficient or produces less waste.	Depends on the type of plastic production • 3D printing technology. • Change over to more modern models of the technology.
6 On-Site Reuse and Recycling 	Use waste generated by processes for similar or alternative purposes in the company.	Internal recycling depends on the type of plastic technology.[40] • In ***injection moulding***, grinders are positioned close to injection presses that generate plastic waste in order to recover, crush and reintroduce the plastic waste into the production process. • In ***rotary moulding***, plastic waste is ground, screened and reintroduced into the process. • In ***thermoforming***, material for recycling is ground, extruded and reintroduced into the production chain as granules.
7 Production of Useful By-Products 	Convert a waste generated by processes to a suitable use elsewhere.	Categorise and keep an inventory of plastic (and other) waste as the first step to understanding potential use by the company or other partners along the value chain.
8 Product Modification 	Redesign the product to reduce its environmental impact during production, use and/or disposal, without compromising product quality.	• Reduce thickness of packaging. • Avoid hazardous additives or additives which make recycling more difficult. • Shift to biologically sourced raw material and material with easier recyclability.

The importance of operational control in the broader plastics industry is widely recognised. In several countries, plastics companies are employing principles of smart manufacturing and better operational control under the banner of Industry 4.0 to achieve productivity gains and minimise material and energy losses. They are using such practices as the use of intelligent sensors, improved plans and designs to eliminate human error, and increased flexibility in production. These fit well within the broader RECP methodology.

Experience

The following three case studies[41] on the use of the RECP methodology in the manufacture of plastic packaging and other single use plastic consumer products all are outputs of the SwitchMed initiative, which is funded by the European Union and implemented by UNIDO, UNEP's Economy Division, and MedWaves, UNEP's Mediterranean Action Plan (UNEP/MAP) regional activity centre. The programme's activities benefit eight countries in the Southern Mediterranean: Algeria, Egypt, Israel, Jordan, Lebanon Morocco, Palestine and Tunisia. The programme focuses on policy development, demonstration activities and networking opportunities. It supports policy makers, eco-innovative SMEs, industries, start-ups and entrepreneurs in the eight focus countries.

Reducing the amount of packaging used

An SME manufactures various milk-based products, which are placed in PE packaging. During a RECP assessment of the company's production lines, it was discovered that the PE acquisition contracts included requirements that went beyond the standards recommended by ASTM International. The contracts required the PE thickness to be 75 µm ± 5% and the width to be 325 mm ± 5 mm, whereas the ASTM standard recommends a PE thickness of 75 µm ± 2 µm and a width of 320 mm ± 1 mm. This deviation from the standard was leading to unnecessary overconsumption of packaging materials. The company was using 5.65-6.15 g PE packaging per litre of product, depending on the supplier, instead of 5.32 g/litre if it kept to the ASTM standard. Company management decided to revise its PE packaging procurement contracts to incorporate the dimensional requirements recommended by ASTM. Management also decided to introduce a systematic dimensional inspection of the incoming packaging and to return to suppliers any non-compliant packaging. This reduced excessive use of PE packaging by 33.1 tonnes/year, or 14.4% of the PE purchased. This translated into savings of a little over €36,700/year.[42]

A company manufacturing household detergents and bleach undertook a RECP assessment. Among other steps in the manufacturing process, the team assessed the step where the pallets with the finished goods were stretch-wrapped using an automatic wrapping machine before the pallets were stored in the warehouse. It was discovered that the stretch-wrapping equipment was based on outdated technology, which was causing high losses of wrapping material. In addition, the stretch wrapping film which this equipment could use could not be less than 23 µm thick. Company management decided to purchase more modern equipment that includes a prestretching mechanism which allows for a better stretch of the film before it is applied to the pallet. The new wrapping equipment can use shrink wrap film as thin as 17 µm, leading to additional reductions in the amount of wrapping film used. By reducing wastage of the film and the thickness of this film, overall reduction of film was 10 tonnes/year. This translated into annual savings of very nearly €27,000/year. The capital investment of installing three new wrapping machines was €12,000, so the payback on this investment, at half a year, was very good.[43]

Increasing the use of recycled plastic in plastic packaging

A company which manufactures PET containers, both for household use and for food applications, decided to undertake a RECP assessment. During the assessment, it was discovered that all the PET containers use virgin PET for their manufacture. It was decided to assess the viability of using recycled PET at least in the manufacture of the containers for household use, given the much lower price of recycled PET. It was determined that this option could be viable for levels of 20% or so of recycled PET in the final product. Company management therefore decided to adopt this option. Its implementation required the installation of a diverting valve at the PET dryer, as well as modifications of the raw material delivery system to facilitate the delivery of virgin PET and recycled PET. Substituting 20% of the virgin PET with recycled PET led to total annual savings €15,000/year. The cost of purchasing a diverting valve was also €15,000, so the payback, at one year, was good. In addition to the environmental benefit of using recycled PET instead of virgin PET, there was a reduction in upstream CO_2 emissions since the production of recycled PET has a significantly smaller carbon footprint than the production of virgin PET.[44]

Industry associations are also making efforts to help their members move towards cleaner operational practices. For example, following the launch of the Plastic Strategy by the European Commission, the industry non-profit association Plastics Europe published the "Plastics 2030 – Voluntary Commitment", with a focus on striving towards resource efficiency as well as increasing reuse and recycling, and preventing plastic leakages into the environment.[45,46] For its part, the Plastics Industry Association (PLASTICS) has launched the Zero Net Waste programme that supports its members in identifying waste reduction opportunities.

Companies from the plastics industry are also taking part in various programmes to reduce leakage of plastics into the environment, focusing on preventing losses. For example, within the international programme Operation Clean Sweep,[47] companies from the plastics industry have committed to practices that prevent the loss of pellets. The programme involves all the actors along the supply chain – manufacturers of plastics, processors, distributors, logistic and recycling companies. They focus on a range of ***good housekeeping practices*** such as identification of potential sources of pellet leaks (loading and unloading), installation of retainers (including for waste), training, monitoring, and engagement with partners along the supply chain.

Policy responses

In several countries, RECP practices are widely known and are followed not only by individual enterprises but also at a larger scale such as in whole industrial parks or along supply chains. Related experiences are also available in several developing countries, often supported by national RECP centres, by organisations such as UNIDO and UNEP demonstrating the benefits of RECP and piloting large-scale approaches, and by further developing methodologies and guidelines, including for eco-industrial parks.

However, upscaling is challenging since the necessary investments, albeit typically profitable, are competing with other more profitable and tangible ones such as capacity enlargements. Adjustments to the policy framework with the objective of facilitating the uptake of RECP practices would therefore be helpful. The major areas where policy intervention can be considered are as follows:

- Since a major driver behind the uptake of RECP by companies is their desire to reduce their operational costs, it is important that they pay the true costs of using raw materials and of generating waste and pollution. On the one hand, this means that governments should

strictly enforce their environmental and health regulations to ensure that companies are paying the proper costs of generating waste and pollution. On the other hand, it means at a minimum that governments should ***remove subsidies*** from all material (and energy) inputs which companies use, so that they pay the true cost of these inputs. It could also mean governments ***modifying their fiscal instruments such as sales tax, VAT, environmental charges, or tariffs***, on raw materials and semi-finished goods, especially where these can be used to prioritise the use of recycled raw materials, of semi-finished goods made with recycled materials, and of remanufactured and reused parts.

- A major barrier to the uptake of RECP by companies is that, despite all the efforts which have been made over the decades, there is still a considerable lack of knowledge about how to implement RECP and what RECP options are available. This is particularly true for MSMEs. Governments can help to ***fill these information and knowledge gaps*** by ensuring that various services are made available to companies, free or at a reduced cost:
  - Awareness-raising courses are made available, to start the process of knowledge and skills building in companies;
  - Training courses are run, to build up in companies the necessary skills in assessment methods and (sector-specific) technical solutions;
  - Information is made available to companies on methods (e.g., guidelines, manuals) and technical solutions (e.g., case studies, information on specific technologies);
  - Audits/assessments can be offered to companies.

  To help in these efforts, governments can ***establish and support industry support institutions***, especially for the MSMEs, that would act as a "one-stop shop" for all of the support services listed above, providing ***ongoing*** support to companies during their implementation of RECP. In addition, or alternatively, they can use existing government-run training institutes like Technical and Vocational Education and Training (TVET) schools to run RECP-related courses, or they can work with industry-run TVETs to ensure they also run offer such courses.
- Another barrier to the adoption by companies of the optimal RECP options is that these require the use of technologies or materials which are not found in the national market and need to be imported. Many companies, especially SMEs, find it difficult to identify and then import such technologies or materials. In this case, governments can adapt programmes they already have in place to ***promote the inflow of industries, processes, technologies, materials, and products***. Specifically, governments can modify the funding of these programmes so that support is given to the new RECP-related challenges, i.e., supporting the inflow of the cleaner technologies and cleaner materials. In certain cases, the desired cleaner technologies or cleaner materials cannot be sourced from another country, or they need to be adapted to local conditions, in which case local R&D might be needed. Governments can adapt programmes which they already have to ***promote R&D***, modifying the focus of these programmes to support new RECP-related challenges.
- Access to capital is another barrier to the uptake by companies of RECP. As the case studies given above demonstrate, Implementing RECP options often requires the company to invest. Since companies cannot always source the funds internally, they need to borrow money on the capital markets. However, this can be challenging, especially for MSMEs: (a) their borrowing costs tend to be higher, because banks see them as higher risk; (b) the amounts they need are not generally very large, which makes them even less interesting to banks; (c) loan officers are very often not familiar with RECP, so they perceive the risks of lending to be even higher. In this case, governments can adapt an approach which has already been used in other contexts, namely they can make ***low-interest credit lines*** available through commercial banks that are aimed at RECP-related investments, or they can offer ***credit guarantee schemes*** to banks for such types of investments.

4.2 Circular economy practices to reduce the plastic waste generated during transportation

Preface

Once products are manufactured, they need to be moved from the point of their manufacture to the point where they will be sold to consumers. In the case of plastic packaging, transporters will first transport the packaging from the factories where it has been manufactured to the factories where it will be used to package other products, and then it will transport these packaged products to the point of sale. In the case of other single use plastic consumer products, transporters will transport them from the factories where they have been manufactured to the point of sale. Depending on the volumes being transported, the distances being covered, the transportation infrastructure available, and the urgency of the demand, transportation can take the form of vans, trucks, trains, ships, and airplanes.

It is in the economic interest of transporters to ensure that as much of the products they carry reach their destination unspoiled and unharmed (in an "as made" condition). However, spoiling, breakage, and other harm to the products can occur, through the mishandling of products during the transportation itself, during loading or unloading, or during other forms of handling, for instance at intermediate warehousing of the products. Transporters also use their own packaging, so-called tertiary packaging. Examples of such packaging include slip sheets, pallets, stretch wrap, strapping labels, etc. Some of these types of packaging are made from plastic. This type of packaging will often be discarded once the products have been delivered to the point of sale.

As noted earlier, although transportation is a key component in the distribution sector, moving as it does manufactured goods from their place of manufacture (or of import) to the point of sales, it also plays an important role in all other stages of the circular lifecycle. For instance, the plastic raw materials will be transported to the sites where they will be used to make packaging or other single use plastic products. Consumers will transport the packaged goods and single use plastic products to their homes or places of work in their car. Alternatively, and increasingly now as consumers purchase ever more of their goods online, retailers will have these goods delivered by van to homes and workplaces. Once plastic packaging and other single use plastic products are discarded, they will be collected and transported to recycling facilities. Once these facilities have recovered the plastic in the incoming recyclate, it will be transported back to manufacturers to reuse to make new plastic products. The circular economy practices outlined below are relevant to all the phases of transportation where products are being transported. However, the transport of waste plastic also has some special characteristics which will be discussed in section 4.5.

Circular economy practices to reduce single use plastic waste generated during transportation

Transporters can adopt two broad circular economy practices to reduce the amount of waste plastic packaging and waste single use plastic consumer products which they generate during transportation.

- They can adopt the RECP methodology to assess their operations and see where they are generating plastic waste, why they are generating it, and what options are available to them to reduce it.[48] While the RECP methodology was initially developed for use in the manufacturing sector, it can be equally well applied –perhaps with some modifications – to any commercial activity.
- They can redesign the tertiary packaging which they use, to reduce the amount of packaging they use, especially where they use plastic packaging. Possible options are light-weighting, using packaging made with materials other than plastic, using plastic packaging that includes recycled plastic, and switching to reusable tertiary packaging.

Experience

Stretch wrapping was invented in the 1970s as a way of unitising a load for shipment, i.e., building one large load on a pallet to be transported rather than many small loads. Stretch wrapping also minimised products from moving and shifting during transportation, a major source of product damage. The economic advantages were such that it was rapidly adopted throughout the transportation sector.[49]

However, poor practices in the application of stretch wrapping can considerably reduce the ability of stretch wrap to protect palleted loads. Therefore, proper training of workers involved in stretch wrapping is critical. In addition (as was described in one of the RECP experiences above), the stretch wrapping technology used can impact on the stretch wrap's viability. Therefore, attention needs to be given to the type of technology which is being used.[50]

While stretch wrap reduces wastage from product damage, it does create a waste stream of its own when the single use stretch wrap is removed upon arrival at the warehouse of the point of sale and is discarded. Various alternatives to stretch wrap exist, although they too generate a certain amount of waste at arrival. It can also be that stretch wrap is being used in cases where it is not really required. Assessments are necessary to determine from a lifecycle perspective which would be the best approach to use in any particular situation.[51]

Discarded stretch wrap can be quite easily recycled, since it is normally made from LDPE. However, warehouse workers need to be properly trained to ensure that the discarded wrap is well handled (e.g., it does not get mixed up with other wastes), and there needs to be a programme which will collect this discarded wrap.[52]

Policy responses

Policy responses are much the same in this case as they are in the case of promoting resource efficiency in manufacturing, i.e.:

- Strictly enforce environmental and health regulations, to ensure that companies are paying the proper costs of generating waste and pollution; remove subsidies from all material (and energy) inputs which transport companies use, so that they pay the true cost of these inputs.
- Build up the knowledge and skills of transportation companies of how to go about assessing their over-consumption and waste generation, and identifying what options are available to them to reduce these.
- Help transportation companies identify and source from other countries solutions which are not available to them in their country, help them with any R&D which they might need to undertake to identify and develop solutions.
- Help transportation companies access the capital they might require to fund their resource efficient options.

4.3 Circular economy practices to reduce the single use plastic products passed on to consumers at points of sale in the service sector

Preface

Many Many businesses and other entities in the service sector consume plastic packaging and other single use plastic products as part of their business model. In this sense, they act as consumers and will be further considered in section 4.4 below.

However, there are a number of businesses in the service sector which stand apart because their "use" of single use plastic products primarily consists of passing these on to consumers, who are then left with the problem of what to do with these products once they discard them. These are a) the retail sector, particularly supermarkets, and b) businesses offering food and beverages to go. These will be the subject of this section, where the focus will be on how these businesses can reduce the amount of plastic packaging and other single use plastic consumer products they transfer to consumers through the services which they offer (and which consumers then have to deal with when they discard them).

As shown in chapter 2, there has been a steep increase in the use of plastic packaging, and the development of the **retail sector** has been a major cause in this increase, being heavy users of so-called primary and secondary packaging.[53] The increase in the use of most plastic (and other) packaging is the result of how the retail sector has developed, especially supermarkets. Instead of having the shopkeeper taking products from shelves behind the counter and weighing out the amounts the consumer is asking for, as was the case in shops the world over before World War II, products are now made available to consumers in standardised packaged units, which they can take off the shelves of a supermarket or a shop themselves in "self-service" style and bring to the check-out desk. As a secondary effect, packaging has become an inherent part of the advertising of the brand and has also become a way of making available to the consumer information about what the product contains.[54] Standardised units of packaged products also make it easier to transport the products over long distances.

With respect specifically to supermarkets, the use of plastic packaging has also been very important in their management of fresh produce. Not only can fresh produce be offered in standardised packages, but the use of airtight plastic sleeves on fresh produce can also significantly reduce the rate of decay of this produce, while plastic's sturdiness protects the produce during transportation and its lightness minimises the fuel costs of transportation.[55]

Greenpeace UK has undertaken a study of the use of plastic packaging in UK supermarkets and how the use of this packaging can be reduced.[56] In terms of weight of plastic packaging used, in 2019 UK supermarkets used a little over 650,000 tonnes. Bottled drinks made up the largest percentage, at 42%, with just three categories – carbonated drinks, milk and bottled water – making up one-third. Processed food to eat at home made up 21%, fresh produce and cleaning products 11% each, while ready-to-eat food and personal care products made up 7% and 6%, respectively. The remaining 2% were made up of miscellaneous products. The order changes when the number of units of packaging used is considered, reflecting diversity in the size and weight of plastic packaging used. These same supermarkets used 56.5 billion units of plastic packaging, of which processed food to eat at home made up 28%, followed by fresh produce at 26%, bottled food at 20%, food ready to eat at 19%, cleaning products and personal care products at 3% each, and miscellaneous products at 1%.The retail sector is also involved in the management of the tertiary packaging which transporters use, since this packaging is often removed in the stockroom of retail stores and ends up having to be managed by them.

The retail sector is also involved in the management of the tertiary packaging which transporters use, since this packaging is often removed in the stockroom of retail stores and ends up having to be managed by them.

For their part, **businesses offering food and beverage to go** make heavy use of single use plastic products: plates, cutlery, clam shells, and so on for the food they serve; cups, caps, glasses, bottles, straws, stirrers etc. for the beverages they serve. It has been estimated that Americans use and discard 500 million plastic straws a year, while the figure stands at 25.3 billion a year in Europe.[57] 40 billion plastic forks, spoons, and knives are used and discarded every year.[58] 500 billion plastic cups are used and discarded every year,[59] many of these coming with plastic caps and stirrers.

Circular economy practices to reduce the amount of plastic packaging and other single use plastic consumer products being offered to consumers

The retail sector

The practices described below specifically have supermarkets in mind, although the principles behind them apply equally well to any retail store, large or small, regardless of the products which they sell.

With respect to **plastic packaging**, supermarkets are rolling out, piloting, or assessing a number of circular economy practices to reduce the amount of this packaging which they use as part of the products which they offer for sale to consumers.[60,61]

- The most radical is for supermarkets to eliminate the plastic packaging they use altogether.
  - In the fresh fruit and vegetable section, where much plastic packaging is used, this means stocking the fruit and vegetables loose rather than in plastic trays or protected by individual plastic net sleeves.[62] Supermarkets can adopt various practices in this case. They can encourage consumers to come with their own reusable containers. In order to maintain freshness if airtight plastic sleeves are no longer used, systems which periodically mist certain vegetables with water can be adopted.[63] Alternatively, supermarkets can spray certain fruit and vegetables with a new material made with plant waste, which acts as a protective seal against bacteria attack as well as loss of moisture, and is perfectly safe to eat.
  - In other fresh food sections (fish and seafood, cheese, bakery), supermarkets can encourage customers to come with their own reusable containers.
  - In the dry-goods section and in the drinks section,[64] supermarkets can offer customers refills of their own reusable containers which they bring to the store. Alternatively, they can join programmes where customers do their refilling through an online programme which uses standardised reusable containers. Unless the products are sold under the supermarket's own label, this would require supermarkets to work together with the manufacturers of the products to obtain their agreement to, and participation in, such programmes.
  - Where supermarkets sell products in multipacks, they can eliminate the multipacks and sell the products individually; if they give consumers purchasing multipacks a discount, they can offer the same discount when the same number of individual products is purchased.
  - At the check-out counters, supermarkets can eliminate plastic bags, either replacing them with, e.g., paper bags, or encouraging consumers to come with their own bags. Supermarkets can also eliminate the use of plastic bags in deliveries of online shopping.
- Supermarkets can also reduce the plastic packaging they use:
  - Where products include a lot of water (e.g., liquid cleaning products), supermarkets can offer the product instead in a concentrated

liquid form, or as tablets, or as reusable pouches, with the customer adding the necessary water at home. This lessens the amount of packaging required (and reduces transportation costs). Unless these products are supermarkets' own brands, this would require them to work with the manufacturers so that the latter offer the supermarkets these products in the desired form.

- They can work with their suppliers to ensure that the plastic packaging they do use is light-weighted to the greatest extent possible.

- Supermarkets can ensure that whatever remaining plastic packaging they do use is recyclable or compostable/biodegradable – and is clearly labelled as such. This could well require working with the manufacturers of the products they sell in their stores and/or the manufacturers of the plastic packaging in which these products are sold. It could also require them to work with the relevant standardisation bodies to create standards defining terms such as "recyclable", "compostable", "biodegradable".

  - In the particular case of the fresh produce section, they can make biodegradable bags available to consumers in the place of plastic bags, in which to place the loose produce.

With respect to **other single use plastic consumer products** which are sold under supermarkets' brand name, and where therefore they are responsible for the product design, supermarkets can consider the following design questions:

? ***Can the single-use plastic products currently being offered to consumers be replaced with more durable, multi-use products made with plastic or other material?***

? ***Can they be replaced with products made with more easily recyclable or renewable alternative materials?***

Where supermarkets sell the single use plastic consumer products of other brands, they can encourage the latter to consider the same design questions, or they can opt to identify alternative products which they could sell in their place.

Businesses offering food and beverage to go

These businesses can adopt similar circular economy practices to those outlined above for the retail sector:

- They can eliminate the use of single use plastics altogether.
  - They can simply stop offering customers some of the single use plastic products which they used to give them with their food and beverage, e.g., straws.
  - They can encourage their customers to come with their own containers, e.g., coffee mugs, or they can create or join a programme offering refillable containers.
  - At check-out, they can eliminate plastic bags, either encouraging customers to come with their own bags or using, e.g., paper bags.
- They can reduce the amounts of plastics used in the single use products they offer to their customers.
  - They can choose to purchase their single use plastic products from manufacturers which have light-weighted them.
- They can ensure that whatever remaining single use plastics they offer to their customers is compostable / biodegradable and/or recyclable and/or is made from (at least a certain percentage of) recycled plastic.
  - They can work with the designers of the single plastic products they use to make them out of biodegradable bioplastics.
  - They can use alternative single use products made of a completely different material, e.g., wood.
  - They can substitute single use products made with difficult-to-recycle materials, e.g., expanded polystyrene, with equivalent products made with easier-to-recycle plastic.
  - They can work with the designers of the single use plastic they use to increase the amount of recycled plastic used in their manufacture.

Experience in the retail sector[65]

Elimination of packaging

Several supermarkets have been eliminating packaging from a number of their counters. The US supermarket **Trader Joe's** recently eliminated plastic packaging around apples, potatoes and tomatoes. **Aldi** in the UK has stripped the plastic from their tomatoes, broccoli, potatoes and aubergines, and are rolling out the programme for cabbages and cauliflower. **Morrisons** in the UK offers plastic-free fruit and vegetables in 60 stores. **Sainsbury's** has eliminated plastic trays from asparagus, sweetcorn, tomatoes, carrots and herb pots.

As part of making fruit and vegetables available loose, a number of supermarkets are encouraging their customers to bring their own reusable bags. They are also encouraging customers to use reusable containers at other counters. **Metro** in Quebec, Canada, allows its customers to bring their own reusable containers and zipper bags to take produce from the deli, meat, ready-to-eat meals, fish and seafood, and bakery counters.[66] **Asda** in the UK encourages their customers to bring their own reusable bags in which to put their fruit and vegetables. **Morrisons** in the UK has been allowing customers to fill their own containers with items from the meat and fish counters since 2018. **Waitrose** and **Sainsbury's**, also in the UK, allow customers to bring their own containers to the meat, fish or cheese counter.[67]

The same has been happening to some degree with dry goods and liquid goods. This approach was started by **zero-waste stores**, the first of which came into operation in the UK in 2007. These are specialised stores with no packaging, offering instead a range of loose produce for sale. Most of these stores stock everyday items such as rice, pasta, pulses, nuts, and spice. Some will also offer refillable washing-up liquid, haircare, laundry detergent, and liquid soap. Other possible items are loose tea, oils, and sauces. Customers bring in their own containers and fill them up with the desired amount of produce, and they are then charged by the weight of the produce they have taken.[68] Some mainstream supermarkets are beginning to adopt this approach. After testing the approach in one of its branches, focusing on pasta, beer on tap, and pick 'n' mix frozen fruit, **Waitrose** in the UK has been rolling out the scheme to other of its branches. **Morrisons** has been trialling a refill scheme for produce such as pasta, seeds and frozen fruit. **Asda** in the UK has also been trialling a refill scheme for loose products such as pasta, rice, tea, coffee and cereals. Customers can bring their own containers or buy reusable containers in store and use these.

The UK supermarket chain **Tesco** has been trialling the removal of wrapping from multi-packs while still giving the offered discount for the equivalent number of single packs. If it works, other options would then include scrapping multipack tins and getting rid of binders on beer cans. **Aldi** in the UK has scrapped plastic packaging on multipacks of tinned tuna.

Many supermarkets the world over have been eliminating the use of plastic bags, both within their supermarkets and for their home delivery orders. For instance, in South Africa **Shoprite**, **Woolworths**, as well as **Spar** have focused on phasing out-single use plastic shopping bags, while **Pick n Pay** has been running a "Make Plastic Bags Extinct" campaign since 2008. Many of these retailers have also got involved in other segments of the lifecycle, for instance in the installation of plastics sorting facilities, and in giving out information to consumers.

Corrigan Corporation is the US leader in offering misting systems to supermarkets for their vegetable produce sections. The company has been marketing its systems since the late 1970s. There is 80% penetration in the US market, but very little penetration in other parts of the world.

A number of US supermarkets are using a protective, edible coating made by the US company **Apeel**[69] on some of their fresh produce to increase their shelf-life without using packaging. Some UK supermarkets are trialling this approach. An Israeli agri-tech start-up has developed its own biodegradable coating, **Sufresca**.[70] Made up of natural food ingredients, this creates a breathable coating on fresh produce, partially blocking the exchange of gases that lead to decay.

The following are two examples specifically about bottled water. They are happening outside of the retail sector, but if successful will reduce retail sales. The Mayor of London has partnered with Thames Water to install a network of more than 100 drinking water fountains in busy and accessible areas of London. This is part of a range of measures taken by the mayor to reduce the number of single-use plastic water bottles used in London and provide free access to healthy tap water.[71] While the quality of drinking water in London is good, this approach can also be used,

with variations, in places where the quality of drinking water is less good. In the southern region of Brazil, the quality of drinking water has been steadily decreasing over the years. This has led to a growth in the purchase of bottled water. To counteract this trend, a use-oriented product-service system has been created, which offers water to consumers in certain places. They collect the water in their own containers and pay for the water which they take. To assure consumers that the water is of drinkable quality, it is purified through reverse osmosis.[72]

Reduction in the use of packaging

The UK company **Splosh** offers products for washing machines, dishwashers and personal use. The products are initially delivered in reusable bottles. Subsequent orders then come in pouches filled with concentrated liquids. These can be poured into the bottles and diluted with tap water. Using concentrates in pouches reduces discarded plastic packaging by around 90%. In addition, the pouches can be returned to Splosh for reprocessing into other products, which completely eliminates plastic waste.[73]

Procter & Gamble has created a line of plastic- and water-free products called "DS3 Clean" swatches. The swatches are the size of a tea bag and foam up when mixed with water, making them much lighter and easier to transport than traditional products. This innovation removes 80% of the weight, 70% of the space, and 75% of the emissions compared with traditional products. The product line includes laundry detergents, surface and toilet cleaners, as well as personal care products.[74]

Use of reusable packaging

Terracyle in the US has launched Loop[75], an e-commerce platform, in partnership with Procter & Gamble, Nestlé, PepsiCo, Unilever, Mars, Clorox, Coca-Cola, Mondelēz, Danone and about a dozen smaller brands. The European retailers Carrefour and Tesco, logistics company UPS and resource management company Suez are also engaged in the system. Loop brings back the old "Milkman" model by delivering cleaning, personal care and food products bought online in reusable packaging. Packaging is returned in tote bags provided by Loop and refilled.

The Chilean company **Algramo**, working with multinational consumer product companies like Unilever, Nestlé, and Colgate-Palmolive, has built up a system that allows its customers to refill branded household products like washing-up liquid, clothes washing liquid, and general cleaning products by using smart powered dispensing machines located in supermarkets along with packaging chipped with RFID which they purchase from Algramo. Customers credit their account through an app and bring their smart packaging to an Algramo dispenser. The machine will recognise the packaging and dispense the right product at the desired quantity without the need for login or payment. This allows the normal packaging used in these products to be completely eliminated. It also means that the brands can sell their product at considerably lower bulk prices (packaging represents about 30% of the overall price). The company plans to extend its network of dispensers, installing them in convenience stores and service stations.[76,77]

A number of Indonesian start-ups are offering the same or similar service:

- **QYOS** is partnering with Algramo to set up the same system in Indonesia.
- Working with brands, **Alner** provides them with returnable and reusable packaging which is suitable for a wide array of products, from household cleaners to personal care items and food products, and which can be used up to 20 times. It has set up a number of community-based points of sale at locations such as waste banks, warung stores, and other retail locations, where consumers can purchase the products in the reusable packaging. In the same places, it installs reverse vending machines, which customers can use to return their used packaging and receive cash back for each piece of Alner packaging they return. Alner provides the community the necessary training and support to manage this system. It operates state-of-the-art cleaning facilities to ensure that all returned packaging is thoroughly cleaned and sanitised before it is returned for refilling.[78]
- **Siklus** offers consumers a home delivery solution. Using the company's app, consumers can order the product they need. A specially-designed motorcycle will come to the house, and consumers, using their own packaging, can get a refill.[79]

A number of Ghanaian companies are also offering a similar service:[80]

- **Sava Shea Co. Ltd.**, a cosmetics company, sells its products in big refillable containers to regular customers, who then transfer the product to smaller containers at home. Once the refillable containers are empty, they can go back to have them refilled. The company also offers a more traditional deposit scheme, whereby it gives a 10% discount to customers who return their cosmetics containers in good order (i.e., no serious scratches or blemishes).
- The start-up **SPEX Smart Pack Exchange Co. Ltd**. has partnered with a number of restaurants and delivery companies to deliver prepared meals at home. The food is delivered in stainless steel containers, which are taken back to the company for washing and disinfection when a user orders their next meal.

Use of packaging made with alternative materials

Many supermarkets now offer biodegradable plastic bags in the fresh produce section instead of plastic bags, in which customers can put loose produce.

In North American supermarkets, it is routine to offer customers paper bags at check-out instead of plastic bags. Some supermarkets will sell reusable bags made of a variety of materials. Note that it is not always clear that these alternatives are actually better than plastic bags from an environmental point of view. The key to any alternative (and indeed to plastic bags) is to reuse them over and over again, which requires bags which are sturdy enough to withstand extensive reuse.[81]

In Ghana, a number of companies – **Shea Butter Boss, Bubune Skin Care, Nyca Pro Enterprise** – offer their products in biodegradable containers made from coconut shell. Such containers are two to three time more expensive than plastic containers, leading to an overall increase in the cost of products of 20 to 40%, but the companies' promotion of these products as being more natural has a following in the market.[82]

Making plastic packaging more easily recyclable

The South African retail business **Pick n Pay** features recyclable packaging in its PnP Green range.

A number of UK supermarkets have removed black plastic from all their own-label ranges. In terms of recyclability, black plastic is problematic because it is not detectable by most sorting machines. Its presence in the recycling stream also makes it more difficult to recycle other types of plastic. This, coupled with the fact that there are few uses for recycled black plastic due to its lack of colour versatility, means that there is little incentive to create better sorting technology to address the problem.

Again because of difficulties in recyclability, a number of supermarkets in the UK have switched from PVC and polystyrene trays to recyclable alternatives.

Experience with businesses offering food to go

Important efforts have been made by businesses in the food and beverage sector which traditionally have included single use plastic products in their service offerings. For example, **Starbucks** has stopped providing plastic straws. **KFC**, **Danone** and **Nestlé** have joined the move towards elimination of single-use plastic. Many retailers, which also now offer food and beverages to go, are acting on the single use plastics that go with this. For instance, the South African retailers **Shoprite**, **Woolworths**, and **Spar** have been phasing out their offerings of single use straws and cutlery.

The company **RECUP** offers a reuse scheme to cafés and coffee chains in Germany, as an alternative to their using single-use plastic coffee cups. Coffee drinkers pay a deposit when opting for the reusable cup and can return the empty cup to any RECUP partner in exchange for their original deposit. RECUP partners pay a membership service fee to finance the operation of the deposit scheme and have access to a mobile app. All RECUP partners are required to clean and reuse the cups returned to them. There are 25,000+ participating stores. RECUP is currently expanding the system by testing it with bigger partners, such as McDonalds and Deutsche Bahn..[83]

Policy responses

Governments have a number of policy instruments available to them to encourage retailers and businesses offering food and beverages to go to reduce, if not eliminate, their use of plastic packaging and other single use plastic consumer products.[84]

- Governments can use various regulatory approaches:
  - They can ban or restrict the use of certain single use plastic products, e.g., at least 84 countries restrict the retail distribution of plastic bags (for more details, see[85]), mostly in tandem with restrictions on their manufacture or import; at least 22 countries ban specific products, such as plates, cups, and utensils, while 16 countries ban specific polymers, most commonly polystyrene and expanded polystyrene.
  - In the case of plastic bags, they can regulate their thickness, looking to restrict or ban the use of very thin bags (at least 38 countries have such regulations).
  - They can regulate the material composition of certain single use plastic products (e.g., pushing for the adoption of biodegradable plastic bags or bags containing a minimum percentage of recycled plastic).
  - They can promote the adoption by consumers of reusable alternatives.
  - They can institute Extended Producer Responsibility regulations covering single use plastics – this will be dealt with in more detail in section 4.4.
  - They can set legally binding national targets on the reduction of single use plastic products.
- They can use market-based instruments:
  - They can levy a fee on single use products at the point of sale, e.g., at least 30 countries have instituted a levy or charge on plastic bags given to consumers; at least 29 countries have enacted some type of tax on other single use plastics, either as a special environmental tax, waste disposal fees or charges, or in the form of higher excise taxes for single-use plastics.
  - They can provide incentives for consumers to be provided with reusable alternatives.
  - They can set up a deposit-refund scheme for certain types of single use plastic products, most commonly plastic beverage bottles. In the deposit-return schemes for single use plastic beverage bottles, a small deposit is added to the price of the product and returned to the customer upon its return. Such schemes are being implemented in 40 countries and 21 US States in some form. These schemes have tended to increase recycling of bottles to 80-95%.[86]
  - They can use their public procurement to help create markets for alternatives to products with plastic packaging and other single use plastic products. For example, in countries with feeding support programmes for children in school (e.g. milk, other nutritious foods), governments could prepare the criteria used in the call for bids to favour options which reduce or eliminate single-use plastic packaging (such a policy could be twinned with other government awareness-raising programmes that have the students collect and sort remaining waste at schools, as part of their education).

As can be seen from the examples give above, the retail sector is ripe for the ***development of new circular business models***. Governments can encourage, facilitate and support these new business models. While the specific public policies that will best facilitate the introduction of new circular business models depend on the particular area of service/application, the general principle would be to identify and remove the main barriers and risks and introduce incentives for the entrepreneurs developing the business models (as well as for the consumers to whom these models are aimed). In general, information about new business models would need to be disseminated and partners across the value chain would need to be encouraged to actively seek information and act on it. Public policy might extend support – financial, technical and scientific – to the partners who aspire to pilot new circular models.

4.4 Circular economy practices to reduce the plastic waste generated by consumers

Preface

As figure 4 shows, consumers are critically important actors in circularising the flows of plastic packaging and other single use plastic consumer products. Like all other actors in the circular economy, they can help to minimise material flows by using these plastic products efficiently. But it is only consumers who can also minimise the flows of these products by choosing to purchase alternatives to these products which are not made of plastic or which are made at least partially with recycled plastic, or which are made with less plastic, or to purchase versions of these products which are durable and multi-use. It is also only consumers who can increase the recycling of these products once they are discarded by choosing to place them in recycling programmes.

Note that the term "consumers" is normally understood to mean individuals, often living in households, who purchase products for their own private use and consumption. However, all actors in an economy are also at least in part consumers:

- Businesses and other entities in the service sector purchase goods which are packaged in plastic packaging or purchase other single use plastic products; these are then used to deliver their services. The healthcare sector, for instance, consumes large quantities of single use plastic products. The more common such items are gloves, masks, and disposable protective clothing; intravenous solution bags and administration systems; disposable plastic syringes; and nappies. The hospitality sector is also an important user of goods packaged in plastic packaging and of other single use plastic products.
- Manufacturers also purchase goods which they use to make their products (so-called operational inputs). At least some of these will come in plastic packaging (e.g., cleaning fluids).
- Farmers and other primary producers also purchase products to produce their goods, and some of these will come in plastic packaging (e.g., some of the pesticides and fertilisers they use); farmers also use large quantities of single use plastic sheets.

Nevertheless, the rest of this section will focus on household consumers, although it should be kept in mind that the circular economy practices and policies which are described below are often just as applicable to these other consumers in the economy.

Although consumers have a key role to play in the circularisation of economies, they can be greatly helped – or impeded – in playing this role by decisions taken upstream of them in the value chains. Thus, as we have seen from the previous section, consumers "voting" with their wallets at the points of sale, deciding to purchase a particular product or service, or to reject it, can be greatly influenced by the choices – or lack thereof – made by retailers and businesses offering food and beverage to go. Through their decisions, the latter can make it easier – or harder – for consumers to adopt the circular practices described above: opting for non-plastic products, of for plastic products (partially) made with recycled plastic and/or less plastic, or which are durable and reusable rather than single use, or which are easily recycled. As such, retailers and businesses selling food and beverages to go have a significant role in influencing circular choices by consumers, especially as these businesses become increasingly large and global in their reach.

Consumer concern about single-use plastics and choices are impacted by a variety of factors, including price and availability of alternatives or measures that prevent access to single use items. For instance, a survey by Ipsos MORI in 2018 in the UK for King's College Polling Club found that almost all of the respondents were concerned about the effects of plastic waste on the environment. Respondents were ready

to make environmentally sound choices, but without paying extra or avoiding suppliers with unsustainable practices. They preferred actions directed at other actors along the supply chain, e.g., taxing retailers for unrecyclable products, municipal governments increasing their spending on recycling, naming and shaming those lacking in recycling efforts.[87]

Circular economy practices to reduce the amount of single use plastic products used and discarded by consumers

As just mentioned, household consumers can adopt a number of strategies to reduce the amount of plastic packaging and other single use plastic consumer products which they use and then have to discard.

- Decisions at the point of sale are particularly important in this case. They can choose purchasing options which reduce, if not eliminate, the amount of plastic packaging and other single use plastic consumer products they purchase.
- Once they have used the single use plastic products for their original purpose, consumers can extend their useful lives by reusing them in a variety of ways, either for their intended use or – through repurposing – for another use.
- Once the single use plastic products have come to the end of their useful lives, the main action consumers should take is to properly segregate these discarded products (if segregation programmes are available to them), to maximise their chance of being recycled properly, or at a minimum ensure that these products do not get littered or otherwise leak into the environment. This will be dealt with in the next section, on recycling.

Examples

At the Point of Sale

With respect to plastic packaging, and as detailed in section 4.2.2., consumers can choose to do their shopping with their own reusable bags and containers (if the retail stores they use allow this; they can pressure their stores to allow it if they do not). They can choose to use refill stations in their retail stores if the latter offer this service (and can pressure them if they do not). Alternatively, they can join programmes which offer to deliver them their produce in reusable containers.

With respect to single use plastic consumer products, they can simply refuse such products when they are offered them. Alternatively, as detailed in section 4.3.1., they can choose to join programmes which offer reusable alternatives (e.g., reusable cups for hot beverages). They can choose to take their custom to businesses which offer more compostable or more recyclable alternatives to the single use plastics they have accepted in the past.

During Use

The internet is replete with sites that give consumers suggestions on how to reuse single use plastics in an artisanal way: “60 ways to reuse plastic bottles”,[88] “40 brilliant ways to Reuse Plastic Cups for a Greener Planet”,[89] “28 Creative Ways to Repurpose and Reuse Plastic Spoons”,[90] “10 Uses for your Old Plastic Plates”,[91] and so on. Practically speaking, however, these kinds of reuses can only have marginal impacts on the amount of single use plastic products which consumers discard, given the limited number of reuse options and the sheer quantity of these products which consumers end up with.

Policy responses

Consumer education is an important factor in guiding consumers to select products and services that could reduce the amount of plastic packaging and other single use plastic consumer products in use. Multiple campaigns accompanying the introduction of desirable products have been considered successes. However, in the absence of continuous effort, consumers might only temporarily adopt the action. For example, in South Africa the levies on single use plastic bags did not result in consumers necessarily choosing more environmentally sound alternatives. Initially, the levies did lead to a drop in consumers accepting plastic bags in stores. After a while, however, they simply integrated the levies into their purchasing budget. Generally, as in the case of any required behavioural change, ***consultations prior to actions*** as well as ***ongoing feedback on results from introduced actions*** and ***leadership by high-level decision makers*** have proven to be important for success.

While well-designed campaigns are necessary for facilitating consumer choices, attention also has to be given to education. The UN Decade of Education for Sustainable Development (2005-2014),[92] with its Global Action Programme on Education for Sustainable Development (ESD), focused on developing competencies that enable critical choices, including those in the area of consumption/use. Governments can empower users of products and services by ***mainstreaming ESD and consumer education through formal and informal educational curricula. Assessment of policies and practices, consultations*** with key stakeholders, national/regional and sectoral ***guidelines for implementation*** of education for sustainable consumption could lead to mainstreaming sustainable consumption practices. Experience with such action exists in Indonesia.[93]

Incentive schemes can play a useful role in encouraging good habits in consumers. For instance, as has already been noted in section 4.3, deposit-return schemes have tended to improve returns and recycling levels of plastic bottles quite significantly.

In relation to bulk consumers, green (or sustainable) public or private procurement has the potential to become a powerful instrument, albeit so far with mixed results due to difficulties in clearly defining objectives and actions in a forward-looking approach – a complex undertaking in itself. On the other hand, a case study example from a Swedish public entity has shown the potential to shift the focus from consumption of products to services provided with the help of this instrument.[94]

As was made clear in section 4.3, ***partners along distribution networks*** play a significant role in facilitating circularity practices by consumers. Some of them, such as large retailers, have already proven impactful in minimising plastic pollution. Thus, the policies discussed earlier, when applied to them, could also indirectly put consumers in the position of being able to adopt circular practices.

4.5 Circular economy practices to increase recycling of single use plastic products discarded at the end of their useful lives

Preface

In a circular economy, end-of-life is defined as the moment where discarded products are collected and then sent on to facilities where the material resources embedded in those products are extracted and brought back into the manufacture of new products through recycling – or in the case of biological materials through their use to regenerate ecosystems. In the specific case of plastic packaging and other single use plastic consumer products, this means managing correctly the three main steps in the overall recycling chain: collection, sorting, and recycling proper.

In many countries, these three steps are often not happening well, usually when there are insufficient stimuli, normative or financial, to keep these, potentially useful, resources in circulation in the economy. In other words, the poor recycling levels for discarded single use plastic products is often the result of market failures. Economic considerations are possibly the most serious impediment to the return of low value, fast moving plastics into the material loop. Some of these are listed below:

- The currently mostly low waste tipping fees for landfills discourage the more expensive collection, sorting and recycling operations; the seemingly obvious solution of simply increasing tipping fees will not work because operators begin to circumvent the fees by illegally dumping the wastes;
- A level playing field does not exist between recycled (secondary) plastics and virgin plastics; the latter benefit from the huge fossil-fuel subsidies;[95]
- Plastics recycling is not always enjoying the benefits of economies of scale, being hamstrung by poor cooperation from consumers and the lack of the collection and separation systems and infrastructure that recycling requires.

Circular economy practices to maximise the recycling of discarded single use plastic

Separation at source

The recycling cycle starts with the consumers. Where governments have introduced regulations requiring separation at source, consumers can minimise the amount – and therefore the cost – of the downstream sorting which is later required by properly separating in their homes or in their businesses discarded plastic packaging and other single-use plastic consumer products.[96] In turn, the efficiency with which consumers segregate depends on consumers' level of awareness of the problem and their willingness to act on it. As far as individual consumers living in households are concerned, their responsibility for supporting recycling of single use plastics generally finishes there. In many legal systems, commercial and business entities are instead responsible for also hiring the transporters which haul their plastic (and other) wastes away and for choosing the companies which will recycle the plastic (and other) wastes.

Collection

The next step in the cycle is the collection from households and other sources of the separated plastic streams for their onward transfer to the sorters and recyclers. This is another phase of transportation in the circular lifecycle, but as mentioned in section 4.2, it differs from the other phases in one important way. In all the other phases of transportation, the goods that are being transported have a recognised value in the marketplace, so it is in the interests of the transporters to take the goods to the correct drop-off point and to lose as little as possible of the goods in transit. Historically, many discarded products were also considered to have value and were extensively recycled, but in the richer, more developed countries, this is not generally the case anymore. Many types of discarded products are perceived to be waste and thus have no value, indeed to have negative value since it costs to have them disposed, which is an incentive to dump them illegally. This has led these countries to enact laws and regulations strictly controlling the transport of waste: waste transporters must be permitted; there are regulations governing the design and operation of the vehicles transporting the waste, to ensure, among other things, that waste is not lost in transit and becomes litter; there is a waste manifest system, which allows the government to control where wastes have been taken, from the point of generation to the drop-off point, to ensure that the wastes have not been dumped and that they have been handed over to entities which are also permitted. The collection of household or domestic wastes, which is the category to which discarded plastic packaging and other single use plastic products generally belong, is normally the responsibility of municipal governments, which either do the collection directly or contract it out to permitted private companies; in cases where the segregated

PET is a popular target for these informal operators. In Western Cape, South Africa, waste pickers recover 90% of discarded PET.

plastic wastes are subject to Extended Producer Responsibility (EPR) regulations, this responsibility is instead taken on by the EPR consortium – see below. These countries now have in place a well-defined formal collection infrastructure for household waste, with specially designed bins and bin bags to hold the waste and vehicles to take the waste. To the extent that governments have put in place requirements for separation at source, the collection vehicles collect discarded plastic separately and deliver these to sorters and recyclers.

In many developing countries, on the other hand, regulations governing the collection and disposal of household waste are still weak. As a consequence, there this little if any formal collection infrastructure, leading to much dumping of household waste. However, contrary to the developed countries, a good number of discarded products still have value and informal collectors and aggregators have stepped in to take advantage of this economic opportunity. They play a serious role in capturing the value which discarded products still have and contribute to high rates of recycling for some streams, including discarded plastics. In urban China, for example, informal waste collectors account for an estimated 17-35% of municipal recycling.[97] In Saudi Arabia, the informal sector is largely responsible for the country's waste recycling.[98] The role of informal recyclers is particularly notable in the area of some plastics. For instance, the informal sector in India has a significant role in recycling of post-consumer plastic waste (as well as in the running of the waste management system in general). PET is a popular target for these informal operators. For instance, in Western Cape, South Africa, waste pickers recover 90% of discarded PET.[99] Estimates suggest that informal recyclers save up to 30% of landfill space by diverting materials from final disposal. In so doing, they reduce collection and transportation costs, resulting in cost savings for municipalities.[100]

Large numbers of persons are engaged in these informal collection operations. Up to 2% of the populations in Asian and Latin American cities makes their living by scavenging recyclables.[101] Estimates for India show that about 1% of the urban population is engaged in the informal recycling sector.[102] While the formal waste sector in South Africa employs 30,000 people, the informal sector employs two to three times this number. These informal operators often work under often poor health and safety standards.

Greatly flexible in their organisation, these informal operators and aggregators show a high degree of adaptation to changing circumstances. Nevertheless, the emergence of more formalised collection systems in cities in the developing countries is leading to their disappearance, as they increasingly come under regulatory pressure and are subject to falling profit margins. Some reports indicate that this is having the unintended consequence of putting strong pressure on the new waste management infrastructures, resulting in their inadequate functioning.[103] It has been argued that it would be better to formalise the informal collectors and aggregators and integrate them into the new waste management infrastructures or into the new structures created by the move to circularity, in, e.g., reverse logistics and washing services.[104] South Africa has developed guidelines for the integration of the informal waste pickers into the formal economy.[105] UNIDO has been supporting the implementation of the guidelines for the integration of the country's pickers.

Recycling

The final step in the cycle is the recycling itself, often preceded by a further sorting step to remove extraneous materials which have become mixed in with the plastics. Sorting is definitely needed if discarded plastic is mixed with other wastes: household wastes in many countries are still collected all mixed together, and even a number of segregation programmes allow discarded plastic to be mixed with materials from which they can easily be separated mechanically, e.g., metals.

Currently, the more common type of recycling operation for plastics is **mechanical recycling**. In this operation, the discarded plastic products are mechanically sorted into fractions of similar polymers for reuse, particularly the thermoplastics. Sorting technologies use a combination of automated and manual processes. Near infrared (NIR) technologies are used to determine the polymer type, with optical colour recognition sorting plastics into clear and coloured fractions.

Numerous other sorting technologies and processes can be used, including X-rays, density, electrostatics, melting point determination, hydrocyclones, selective dissolution, as well as manual sorting. Plastics can then be ground into flakes, which can be further separated using sink/float methods, air elutriation and heat discoloration for further optical separation.[106]

While this operation is not very costly, there are some critical gaps. One is the lack of sorting methods at scale to differentiate food-grade plastics (which command higher prices) from other recyclates. Accurate polymer marking systems would allow such sorting as well as aid with another critical gap, the sorting of multi-layered materials. Mechanical recycling has mounting difficulties with ever-growing number of products containing multiple polymers in their components or multiple-layer plastic products made of different polymers. The result is not very pure, low-quality recovered plastic. A third critical gap is that mechanical recycling cannot currently separate out the various additives included in plastics. As a result, as a particular batch of plastic is subjected to recurring cycles of recycling, more and more additives, as well as other impurities, will accumulate in the material, increasingly reducing the value of the plastic as well as possibly making it more harmful to the health and safety of consumers. This puts a limit on the amount of times plastic can be recycled.

Recent publications emphasise that there are a number of upcoming technologies and processes that have the potential to deal with the consequences of unsustainably designed plastics. One of these is **chemical recycling**,[107] which is just now emerging out of the experimental phase. Here, chemical processes convert discarded plastic products back to virgin feedstock (the original plastic monomers or the feedstock used to make the monomers in the first place) for the production of plastics or other chemicals, as an alternative to virgin fossil based raw materials; depending on the process used, the resulting products might also be used to produce fuels. Chemical recycling allows for the removal of additives and other impurities, but it requires considerably more effort and therefore energy input.

Data on costs, efficiency, environmental impacts, scalability and intellectual property rights in respect of chemical recycling could not be assessed as part of this work. However, chemical recycling does currently have a large environmental footprint, especially with regard to its high energy requirements. The GHG emissions generated when producing one tonne of plastic through plastic-to-plastic operations (including collection and sorting) is 19% lower than the emissions of producing one tonne of virgin plastic that is later collected, sorted and incinerated. However, the emissions are 10% higher when compared to producing one tonne of virgin plastic that is later collected, sorted and landfilled. Chemical recycling also has serious unknowns: unproven yields and economics for certain applications in some geographies. Chemical recycling capacities are currently very low; assuming reasonable investment scenarios, it is estimated that by 2040, chemical recycling could provide a solution for about 5% of the plastics volume in short-lived products. While this may seem relatively small, it could be targeted at plastics that cannot be recycled mechanically and have no better solution. In sum, if and when chemical recycling's environmental sustainability is demonstrated through LCA studies as well as its economic feasibility, it can become a synergetic solution to mechanical recycling for products that mechanical recycling cannot manage, including films, mixed polymers, low-value and/or contaminated plastic.[108]

A third alternative is so-called thermal recycling, or, put more simply, using plastic waste as fuel so as to recover its energy content. However, since this is in effect a final disposal practice, it will be discussed in section 4.6.

One of the often-neglected facts in the discussions of circularity is that in the process of recycling, a material gradually loses its quality. It can remain in the material loop but not necessarily for the production of the same line of products, especially if quality requirements for the initial product are higher than those which the recycled material can provide. Thus, the material is downcycled to a less valuable use. Recycling of plastics clearly faces this challenge. One notable development in this field is the emerging practice

of “immobilising” plastic waste by using it as a component in construction materials, for instance in road paving, or any other products expected to have a long lifespan. While such practices might be better than the disposal of plastics in a landfill, the question of plastic safety is often neglected and these practices may allow potential leaks of microplastics and potentially eco-hazardous additives from the plastic components of the new products during use. Finally, when these products eventually come to the end of their lives (e.g., the road goes through complete repaving, and the old surface material is discarded) they will probably end up in a landfill.

Upcycling of discarded plastic to a more valuable use than the original through recycling is also possible in principle, although in practice this would depend on whether the requirements of the higher value product are met by the secondary raw material. For instance, the safety of the residual additives in the upcycled plastic would define its suitability for food packaging, medical applications, children’s products (toys or clothing) as well as other applications with particularly strict requirements for the materials used.

It must always be remembered that while recycling may be economically and environmentally beneficial, it does not necessarily come at low risk to human health and the environment. This is especially true in countries where the recycling infrastructure is not yet adequately developed, where regulations are not yet fully formulated, or where recycling operators are not fully compliant and the government’s enforcement capabilities are weak. In the specific case of waste plastic, it is important to remember that recycling operators can themselves become a serious source of terrestrial and marine plastic litter by allowing plastic waste to escape from their operations. It is therefore important to ensure that the promotion of recycling goes hand-in-hand with the development of the necessary regulatory framework and its enforcement, along with the needed training of operators on good operating practices.

Examples

Separation at source

In 1991, the municipal government of the city of Curitiba, in Brazil, created a programme called "Cambio Verde" (Green Exchange), where citizens are encouraged to bring their segregated organic and non-organic recyclable wastes (the latter stream including much discarded single use plastics) to over 100 waste stations. The wastes can be exchanged for bus tickets, food, and school-books. Participation among Curitiba households is high, reaching about 70%.[110]

Germany has one of the highest recycling rates in Europe for its municipal waste, reaching about 70%. Recycling this waste starts at the household. Already, the majority of German citizens are zero-waste inclined. Their efforts are made easier by the country's waste segregation programme. Households have six separate garbage bins, one for plastic, one for clear glass, one for green glass, one for brown glass, one for paper waste, and one for organic and food waste.[111]

Collection

Plastic Bank and **Henkel** have recently opened three plastic waste collection centres in Cairo. At these centres, waste collectors and other people can turn in collected plastic waste and be paid for it. Plastic Bank then reprocesses the material into "Social Plastic"® which can be reintegrated into products and packaging. Henkel is already using Social Plastic® in several of its products. All the bottles in its Beauty Care brand Nature Box are made of 98% Social Plastic®. The PET bottles of its Laundry & Home Care Pro Nature cleaners are 100% recycled plastic, of which up to 50% is Social Plastic®.[112] To date, the partnership has prevented 10 million kg of plastic waste from entering the environment.[113]

Wecyclers in Nigeria, in partnership with **Unilever** and **Fair Plastic Alliance**, is a pioneer in door-to-door waste collection. It has over 17,000 subscribers, paying them N15 per kg of collected discarded PET bottles (there is a school in Ajegunle where the students pay school fees with discarded plastic bottles). The company collects about four tonnes of discarded plastics daily, providing a reliable supply of materials to the local recycling industry.[114]

RecyclePoints in Nigeria is a waste collection and social benefit venture that collects PET plastic bottles and containers, pure water sachets, LDPE nylon packaging, HDPE packaging containers, among other types of discarded plastic, for further reprocessing into secondary raw materials. It operates an incentive-based scheme whereby consumers are rewarded with "points" when they hand over discarded plastic. They can accumulate the points and use them to shop for household items offered through the iRecycle store.[115]

Recycling

Mechanical recycling: PET is currently one of the most recycled plastics by mechanical recycling. The worldwide leading company in the recycling of PET bottles is the India-based company **Indorama Ventures Public Co. Ltd.** The company has PET recycling facilities not only in India but also in the USA, Mexico, Brazil, Thailand, Philippines, France, the Netherlands and Poland. The company produces a total of 11.3 Mt/year of PET and PTA[116] products, making Indorama the biggest PET bottle manufacturer worldwide. By 2050, the company has pledged to increase the rPET capacity to 0.75 Mt/year, equivalent to 50 billion PET bottles a year. The target for the long term is 25% rPET in production overall.[117]

Chemical recycling: **DEMETO**, a European consortium, is working on chemical recycling of the fraction of waste PET which is difficult to recycle mechanically, as well as polyester. The core technology used by the consortium has been created by **GR3N**, a Swiss-based startup. The technology turns the waste into ethylene glycol and terephthalic acid. The latter can be used to again produce PET, even food grade PET, because the technology separates out all the additives.[118] **PET Refine Technology** of Japan (a member of the JEPLAN Group) is also focusing on PET, using its BRING Technology™ which depolymerises the plastic back to the monomer BHET (bis-2-hydroxyethyl terephthalate). This can then be purified to meet the standards for high quality bottle grade PET.[119] **BASF's** ChemCycling project uses pyrolysis to transform waste plastics (as well as automobile tyres) into pyrolysis oil. The pyrolysis oil can then be used as a feedstock to produce new plastics or other chemicals (or it can be used as a fuel).1[20]

Another line of innovation relates to transforming non-recyclable waste into fuel. **Rays Enserv** in India has developed an Advanced Supercritical Thermal treatment technology to convert polyethylene, polypropylene and polystyrene plastic waste into usable low-sulphur synthetic fuel.

Policy responses

Extended Producer Responsibility (EPR) schemes have been an important policy response with respect to packaging waste in general. Such schemes have been introduced in a number of developed countries, and create economic incentives for manufacturers and importers of packaging products to minimise their use. In many cases, EPR schemes have driven the set-up of better plastic collection and recycling systems. It is difficult to compare the various schemes in use because they vary in coverage (type and number of products covered), type of responsibilities (individual/collective, financial/operational/informational), design of the collection schemes, degree of monitoring (in some cases the schemes are not monitored and producer compliance is not enforced), targets (voluntary/ obligatory), and ways of calculation.[121] While their impact has been felt at the post-consumer stage, the schemes in their original form do not provide sufficient incentives for redesigning products towards greater recyclability (largely, it is weight that is privileged) and so do not necessarily promote recycling over other alternatives when they are discarded. Notable exceptions are the Producer Responsibility Organisations (PROs) CITEO in France and CONAI in Italy, which apply higher EPR fees to non-sortable and non-recyclable packaging and no fees to reusable ones.[122] It would be important to put more attention on the role of EPR in supporting circular economy.

Given the significant role of ***informal recyclers*** in waste collection and aggregation in many countries, ***it is important that EPR systems secure their inclusion*** (practices of such a kind are already well established). Guidelines like those developed in South Africa and mentioned earlier can be used to do this.

It also seems that ***deposit schemes*** have been working rather well in a number of countries, helping to keep material streams clean(er) and, potentially, better suited for the mechanical recycling of plastic waste to secondary plastic material.

With respect to ***other economic incentives for recycling***, policies could aim to disincentivise landfilling, or even totally ban it, as plastic waste management systems and infrastructure are strengthened. While this can be a successful approach for the developed countries, e.g. members of the European Union, developing countries will face substantial challenges and long transition times.

Policy measures aimed at ***facilitating the manufacture of products made with secondary raw materials***, might include (subject to individual national and regional conditions) measures that, simultaneously, address secondary material supply and the demand for products made with secondary raw materials. These policies need to address the dual goal of facilitating consumer acceptance and providing incentives for producers and their suppliers.[123]

Particularly important on the supply side are policies for the ***development of effective infrastructure for separation, collection, and recycling*** to extract and return secondary raw materials to the economy. These are required to secure the necessary volume of discarded plastic which is collected and ensure that it is of sufficient quality. Such policies would prevent loss of material and contamination of resources. These policies can be targeted at the development of infrastructure, particularly at local levels through the empowerment of municipalities with sufficient resources, including finances, and at the encouragement of international investments.

The supply side of recycled plastic materials and products could also be stimulated through a policy mix that ***removes subsidies*** for the hydrocarbons that serve as the input for fossil-based virgin plastic production, that imposes ***differentiated taxes*** on virgin and recycled plastic, and that introduces ***standards for recycled content***. Facilitation of information on recycled content and environmental product declarations can create the transparency necessary for decisions on the use of secondary plastic materials in products, including plastic packaging.

Innovation programmes also appear to be effective in supporting the manufacture of products using recycled and recyclable materials. A number of technology incubators exist with mentorship programmes for entrepreneurs providing ongoing support for innovative products and business models. As mentioned previously, UNIDO's Global Cleantech Innovation Programme (GCIP), supported by the Global Environmental Facility (GEF), is a successful example of such programmes.

The ***demand side*** can be facilitated through various policies which open up larger markets for secondary raw materials. Policies can introduce requirements for minimum recycled content. They can also use public procurement by introducing criteria that privilege products with recycled content. They can reduce consumer concerns about the quality of products made with secondary raw materials by adopting quality standards for products with recycled content. Finally, there can be policies which help consumers make better choices, by introducing easily understandable labelling systems and educational campaigns for consumers.

In the area of informal recycling, there is some experience with integrating informal waste operators into the formal waste sector. The example of South Africa has already been mentioned. In Brazil, waste pickers are seen as part of the semi-formal system.[124] Countries with a strong informal recycling sector could also focus on a variety of areas:

- Model legislation, directly and indirectly related Model legislation, directly and indirectly related to waste and material management, that has provisions for the informal waste sector;

- ***2% which is actually recycled into the same or similar quality applications;***
- ***8% is recycled into lower quality uses;***
- ***4% are lost as process losses during the recycling.***

- Strategies for formalisation, including identification of barriers;
- Practices that improve living and working conditions of informal waste sector workers (issuing identity cards, assuring rights to collect in particular areas, provision of equipment and training, social security, providing spaces for recycling, etc.);
- Practices to integrate waste pickers into local, community-based, decentralised waste management;
- Practices in creating new business models (contractual arrangements, strategies for official registration of enterprises);
- Support for associations and networking of and with informal waste sector workers;
- Awareness campaigns focused on their role in society as well as assessment of the economic and social contributions of the informal waste sector.

Finally, there could be public policies aimed at ***regulating the use of harmful chemicals*** in the production of plastics – both those harmful to human health and the environment as well as those harmful to recycling processes.

4.6 Final disposal

Preface

Disposal, which in today's linear economies is the dominant practice at the end of product life, becomes the least desirable option in a circular economy. Ideally, only a small fraction of material that simply cannot be used in productive cycles would be safely disposed. While this remains the overarching ambition, various forms of treatment and landfilling will continue to represent the main waste management solution for most municipal solid waste in many countries, and also for industrial waste in low- and middle-income countries, for a good number of years to come. This is certainly the case for waste plastic packaging and the waste of other single use plastics. In the case of waste plastic packaging, it has been estimated that only 14% is currently collected for recycling, and even then it is a mere 2% which is actually recycled into the same

or similar quality applications; another 8% is recycled into lower quality uses that are generally not recyclable after use and the remaining 4% are lost as process losses during the recycling.[125] In the near term, how well the remaining 86% is managed in countries' waste collection, treatment and landfilling operations will greatly influence how much plastic escapes into the environment as litter, both terrestrial and marine.

Practices to address challenges of plastic litter at final disposal

Practices to minimise the littering of discarded plastic packaging and other single use plastics already start at the point of collection. In public spaces, there must be sufficient well-designed, well-located bins to collect the packaging and single use plastic products which are discarded, and these bins must be emptied often enough so that they do not overflow. In parallel, consumers must be educated to use the bins and not just drop the discarded products on the ground. For households and commercial entities, there must be regular collections of household waste, and programmes must be introduced to ensure that households segregate their waste, to maximise the recycling of the wastes – see previous section.

The transport of collected discarded plastic packaging and single use plastic products to points of aggregation and the further transport of the aggregated wastes to the site of their final treatment or landfilling must be undertaken with properly designed and operated vehicles which minimise the loss of wastes in transit. Issues surrounding the transport of plastic and other waste are complicated by the fact that there is a strong global trade in wastes. Countries sending their plastic waste to other countries has become a common practice, with the sending countries generally being developed countries and the receiving countries generally being developing countries. Until some 10 years ago, much of the trade in plastic wastes went to China. After China decided to ban the import of 24 types of plastic wastes, because of the problems which their management was causing the country, the global trade in waste plastics was severely disrupted. Any such international movement of wastes must come with an assurance that their transportation and disposal (or other forms of

use at the destination) are done in a safe manner. Regrettably, due diligence is not always exercised.

With respect to the final treatment or landfilling of these wastes, and taking into account the waste management hierarchy,[126] priority should be given to their thermal recycling, where their energy content is recovered and reused, over other forms of treatment and landfilling. Currently, only 14% of waste plastic packaging is incinerated,[127] and it is not clear how much of this incineration includes energy recovery. Typically, plastics produce significant energy during combustion and are therefore good candidates for thermal recycling. However, breakdown processes and subsequent formation of other, potentially hazardous chemicals are an issue. For example, there is the possibility of the formation of dioxins and furans, with the related halogens coming from additives.[128] This requires large-scale incineration facilities with the possibility of controlling process temperatures during and after combustion, and of treating flue gases. Purpose-made waste incineration facilities exist in many countries, and they can treat substantial amounts of municipal and other waste. However, the large investments they require and the need to continuously supply downstream users with heat necessitate a constant and substantial waste stream as input, which might be in conflict with waste prevention efforts. Alternatively, large industrial users of heat, such as cement kilns and steel furnaces, may substitute their current fuel with waste within certain limits, partially avoiding the conflicts mentioned above.

Another 40% of waste plastic packaging is currently landfilled,[129] even though this is the least desirable waste management option for wastes (tremendous value is lost in landfills, not only of what is disposed of but also in relation to the inefficient use of the land). To design and operate landfills which ensure the long-term containment of the wastes deposited in them and do so in a manner which is safe, consideration has to be given to many issues, including the cost of establishing and operating them, the availability of the required technical expertise, the existence of the proper geological conditions, and the potential impact of the site's climatic conditions. Today, many guidelines for establishing landfills are available not only for developed but also for developing countries.[130] Unfortunately, many landfills, especially in developing countries, are poorly operated, which in the case of plastics leads to a significant dispersal of these wastes into the surrounding environment and the eventual leakage of an important portion of these wastes into the marine environment.

The net result of the various inefficiencies along the chain from collection to final treatment and landfilling is that nearly a third (32%) of waste plastic packaging is dispersed as litter into the environment.[131] Much of the this makes up the 9-14 million tonnes of plastic waste which it is estimated entered the oceans in 2016. The world community is now faced with the challenge of dealing with the plastic wastes which have entered the marine environment as well as minimising future dispersals of plastic into the environment.

Examples

Clean-up – riverine collection solutions

The **Ministry of Environment of Egypt** has teamed up with youth volunteer group **VeryNile** on an initiative to ban the use of disposable plastic bags in the affluent neighbourhood of Zamalek. VeryNile organises clean-up campaigns along and on the Nile and works to raise awareness about environmental protection in support of the Ministry. These campaigns are sponsored, for example **Attijariwafa Bank** funded and distributed 4,500 cotton-made bags in Zamalek, while the **Embassy of New Zealand** and the **International Organization of Migration** funded the equipment used in Nile clean-ups.[132] The clean-up campaigns have reduced the amount of plastic entering the Mediterranean Sea.

Clean-up – ocean waste collection solutions

With an estimated five trillion-plus pieces of plastic polluting ocean waters, technologies are being developed to clean up such debris. Different challenges are associated with different debris and locations, in particular whether the debris is floating on the surface, is submerged, or lies on the seabed. Due to the immensity of the oceans, something approaching an almost-complete clean-up or cleaning most of the water in the ocean does not appear feasible. Cleaning along ports and beaches and picking up plastic floating on or near the surface will address only a portion of plastic marine litter.

The technologies best known internationally, developed by the Dutch NGO **Ocean CleanUp**,[133] creates a 600-meter-long floater intended to clean the Great Pacific Garbage Patch. In addition, there are a number of innovators and startups providing technologies and working on the commercialisation of their concepts.

The Indian company **Sagar Defence** has developed the vehicle "Trashfin"[134], which is designed for around-the-clock autonomous, unmanned, solar powered waste collection, and which extracts unwanted materials, gathers data about the marine environment and communicates with other vehicles in the water. The technology is smaller in scale than that of Ocean Cleanup's and is suitable for different applications, e.g., in port areas and closer to shorelines.

As with all the other practices discussed in previous sections, the clean-up technologies are just one strategy that needs to be combined with measures that align the clean-up of plastic litter with the circular concept of development. The technologies are to be further tested and potential impacts of their applications are to be investigated more deeply – a work that is underway.[135]

Much of the work focused on cleaning up plastic litter in the sea and on land is carried out by governments, NGOs and private citizens. Such activities are critical; it is unclear how their costs per tonne of plastic removed relate to the costs of the practices outlined earlier in this chapter. For example, the United States spends around USD 10.8 billion on litter clean up, with spending on cleaning marine litter for West Cost communities exceeding USD 520 million (this includes beach and waterways cleanup). There is also the operation of waste handling infrastructure in the ports. The European Maritime and Fisheries Fund allocated €53 million for such actions for the period 2014-2020.

Policy responses

Although landfilling is the least preferred waste management option, especially in the context of a circular economy, it will continue while the search for and development of better alternatives is under way. Under such circumstances, the safety of landfill operations, whether publicly or privately operated, should be a priority of public policies, with a view to identifying and implementing policies that will eventually divert plastics from landfills. Safe transportation of plastic waste to other regions and countries must also be a priority.

It will also be important for public policies to support research and comparative impact assessments of recycling technologies and practices, to avoid undesirable and unanticipated side effects.

05 Concluding Remarks

Ultimately, pollution of the environment by discarded plastic packaging and other single use plastic products is a sign of market failure. The cost of these products does not include their economic and environmental impacts. Their seemingly low cost in turn leads to excessive consumption and a lack of incentives for their recapture at the post-consumer stage. Yet in a resource-constrained world, the environmentally sound management of plastics, particularly given their resistance to degradation in the environment, needs to be circular so as to ensure their endless and complete recovery. This requires a ***comprehensive, multi-pronged and aspirational plan of action that simultaneously addresses different circular economy practices along the entire value chain***. The challenges to circularity are present at every stage in the value chain: during production, from poor product designs as well as inefficient and polluting production practices; during transportation, from poor operating practices; in the retail sector, from excessive use of packaging and other single use plastic products; during consumption, from a lack of awareness on the part of consumers leading to poor choices, indiscriminate littering, and poor waste management behaviour; during recovery, from insufficient recycling infrastructure as well as poor handling practices during collection and recycling; at the reuse stage, from poor quality in the recovered plastic material as well as its high cost relative to virgin material; and finally, a lack of alternatives to plastic packaging and other single use plastic products that do not compromise consumers' satisfaction and the economics of industrial production. Nevertheless, practices in various countries have already demonstrated that there are technically and economically feasible ways of minimising leakage into the terrestrial and marine environments at multiple points along the life cycle of plastic packaging and other single use plastic products. They also demonstrate a range of policy measures that can encourage actions by public and private actors.

Based on the principles and practices of circular economy, three leverage points, each to be based on a comprehensive set of actions, can be proposed to start preventing pollution of the environment by plastic packaging and other single use plastic products.

1 *Design out waste – retaining plastics within the economy*

Prevention of leakage into the environment of discarded plastic packaging and other single use plastic products by ***closing the plastic materials loop through continual recovery and reuse*** focuses on extending, to the maximum, the life in the economy of the materials making up these products, by using the discarded products as sources of secondary raw materials. Closing the loop primarily requires multiple innovations leading to the adoption of business models offering alternative products suitable for reuse, to products made with alternative materials, to any remaining plastic packaging and other single use plastics being easily recycled, and to technologies that can recycle and reprocess plastics at the highest level of value.

Design based on the vision of the whole lifecycle of plastic materials becomes paramount, not only for materials and products (designed for recyclability/recoverability, without hazardous additives, with minimum material intensity) but also for production processes (based on the principles of RECP), for distribution, for use (with choices leading to preferred products or services), and for recycling.

While the menu of policies aiming to retain plastics in the economy will vary across countries, the strategies for designing them could be guided by the following core principles:

a. ***"Closing the front door"*** by preventing some products ever entering markets in the first place. Examples of how to implement this principle are bans on the production and/or

sale of certain types of plastic packaging and other single use plastic products, e.g. plastic bags, single-use cutlery, cotton bud sticks, and the use of hazardous substances in plastics. The promotion of innovations working towards these goals is another example;

b. ***Providing incentives for the perpetual use of plastic materials.*** Implementing this principle calls for a variety of actions ranging from support for R&D to identify and develop new materials and new product designs, to the creation of conditions for the development of technological solutions for enhanced recycling, to creating a level playing field for recycled (secondary) plastics, to facilitating investments in preferred technologies and businesses, to support for technology transfer, and to support for citizens' education;

c. ***"Closing the back door"*** by adopting measures that discourage leakage of plastic materials from the system. Among these are, e.g., the provision of the necessary infrastructure to capture plastic materials and products before they leak, the creation of the necessary separation and collection systems and recycling facilities, as well as measures for sharing the responsibility for the end-of-life stage of products between producers (EPR) and consumers (behaviour-changing measures such as levies, deposit-return schemes) as well as the use of disincentives (e.g., fines).

These three points are closely interlinked and create the necessary stimuli for closing the material loop which could start to drive the system towards circularity.

2 *Prevent – containing leaked plastic*

In instances where plastic does exit the continuous cycle of use and reuse, it is important to stop its uncontrolled escape into the environment and, ultimately, from polluting the terrestrial and marine environments. Capturing plastic waste is facilitated by a number of factors: ***effective waste and wastewater management systems***, which not only contain plastics properly, but also reintroduce some of them back to the loop; ***safe landfilling practices***, which keep deposited materials contained, possibly until such time as they can be recovered.

3 *Recover – remove plastic material that has leaked into the terrestrial and marine environment*

To complement the multiple measures aimed at preventing new leakage into the terrestrial and marine environments, actions are needed to recapture plastics that have already leaked out – today's plastics legacy of yesterday's poor waste management. The amount of plastic litter – indicated by recent studies as significantly larger than estimated earlier – is a rapidly aggravating and immediate threat to ecosystems, human health and economic and social activities. With the cost of recovery operations currently estimated at many billions, innovations are needed to develop new, more effective recovery technologies and practices.

References

1. https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/glossary
2. https://www.oecd.org/environment/extended-producer-responsibility.htm#
3. UNEP, Turning off the Tap. How the world can end plastic pollution and create a circular economy, 2023. https://www.unep.org/resources/turning-off-tap-end-plastic-pollution-create-circular-economy
4. https://en.wikipedia.org/wiki/Repurposing
5. https://www.unido.org/our-focus-safeguarding-environment-resource-efficient-and-low-carbon-industrial-production/resource-efficient-and-cleaner-production-recp
6. R. Geyer, J. R. Jambeck, K. L. Law, "Production, use, and fate of all plastics ever made", Science Advances, 19/7/2017
7. Cumulative plastic production between 1950 and 2050 has been predicted to reach 34 billion tonnes. UNEP, "From Pollution to Solution: A global assessment of marine litter and plastic pollution. Synthesis", Nairobi, 2021
8. R. Geyer, J. R. Jambeck, K. L. Law, "Production, use, and fate of all plastics ever made", Science Advances, 19/7/2017
9. Ibid.
10. Ellen MacArthur Foundation, "The New Plastics Economy: Rethinking the Future of Plastics", 2013
11. UNEP, "From Pollution to Solution: A global assessment of marine litter and plastic pollution. Synthesis", Nairobi, 2021
12. Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7), e1700782, 19 July. – http://advances.sciencemag.org/content/3/7/e1700782
13. European Bioplastics. Bioplastics Facts and Figures. 2017. https://docs.european-bioplastics.org/2016/publications/ EUBP_Facts_and_ Figures_2017.pdf
14. Geyer, J. R. Jambeck, K. L. Law, "Production, use, and fate of all plastics ever made", Science Advances, 19/7/2017
15. Gallo F, Fossi C, Weber R, Santillo D, Sousa J, Ingram I, Nadal A, Romano D. (2018) Marine litter plastics and microplastics and their toxic chemicals components: the need for urgent preventive measures. Environ Sci Eur. 2018;30(1):13
16. See the glossary for the full description.
17. Haffmans, van Gelder, van Hilte, Zijlstra, "Products that Flow", BIS Publishers, 2018.
18. This involves processes which chemically convert plastic waste back to virgin feedstock for the production of plastics or other chemicals – see section 4.5 for more details
19. In a linear economy, the oil will also be transported to the refineries and – if done in a separate facility – the monomers produced in the refineries will be transported to the facilities where they are turned into plastic resins. The plastic wastes generated during use will also be transported to incinerators or landfills – or dumps – for disposal. However, these forms of transportation will not be considered here because they are an inherent part of a linear economy.
20. OECD (2018), Meeting Report of the Global Forum on Environment: Plastics in a Circular Economy - Design of Sustainable Plastics from a Chemicals Perspective ENV/EPOC/WPRPW/JM (2018)1/FINAL, Environment Directorate.
21. For a detailed review of bio-plastics and other alternative renewable materials, see UNIDO, Reducing Plastic Leakage into the Environment in Africa Sustainable alternative materials, innovative packaging and recycling, 2021, https://downloads.unido.org/ot/27/63/27631829/PlasticReportTechnologies-UNIDO-FINAL-20220823-OnePage.pdf
22. http://www.kaneka.co.jp/en/business/material/nbd_001.html
23. https://www.newlight.com/aircarbon

24. https://www.nihon-cornstarch.com/product/bio_plastic/tabid/160/Default.aspx#1
25. https://www.sulapac.com/sulapac-straw/?utm_term=bioplastic%20straws&utm_campaign=IT+-+Google+Ads+-+Sulapac+Straw&utm_source=adwords&utm_medium=ppc&hsa_acc=4234135278&hsa_cam=19806329972&hsa_grp=147434412192&hsa_ad=651022580111&hsa_src=g&hsa_tgt=kwd-579747048888&hsa_kw=bioplastic%20straws&hsa_mt=p&hsa_net=adwords&hsa_ver=3&gclid=CjwKCAjwyeujBhA5EiwA5WD7_cVm2ZuUa-1DjR8jRPIobgAGLyFbbLbrW2Jk9SyuqcRcXv7wfpGeSxoCFH0QAvD_BwE
26. https://newplasticseconomy.org/assets/doc/NPEC-winners-brochure-2018-23.01.18.pdf
27. https://newplasticseconomy.org/innovation-prize/winners/full-cycle-bioplastics
28. http://low-carbon-innovation.org/frontend/pdf/gcip-iInnovator-profiles-2017.pdf
29. https://www.tecnaro.de/en/arboblend-arbofill-arboform/
30. The BKV – Platform for Plastics and Recovery - https://www.bkv-gmbh.de/fileadmin/user_upload/broschueren /bkv_web_englisch.pdf
31. https://ellenmacarthurfoundation.org/aronax-technologies-spain
32. The Circular Design Challenge winners were announced at the Our Ocean Conference in Malta on October 5, 2017.
33. https://newplasticseconomy.org/innovation-prize/winners/university-of-pittsburgh
34. SwitchMed, :Business case: Design for circularity of food-contact plastic packaging, Israel, 2023
35. https://blog.erema.com/plastics-in-food-packaging
36. Many other types of waste as well as air and water pollution can also be generated in the manufacturing steps. These will not be considered here, although the manufacturing practices described are equally applicable to these other wastes and pollution.
37. https://www.sciencedirect.com/science/article/pii/S0025326X18300523
38. https://www.unido.org/our-focus-safeguarding-environment-resource-efficient-and-low-carbon-industrial-production/resource-efficient-and-cleaner-production-recp
39. R. V. Berkel, Z. Fadeeva (2018), Role of industries in resource efficiency and circular economy, conference paper, 8th International conference on sustainable waste management, India
40. https://www.paprec.com/en/understanding-recycling/recycling-plastic/using-plastics
41. https://www.test-toolkit.eu/best-practices/
42. https://www.test-toolkit.eu/wp-content/uploads/2019/10/Use-of-PE-packaging-to-the-strict-requirements-of-the-ASTM-standard.pdf
43. https://www.test-toolkit.eu/wp-content/uploads/2019/10/Efficient-wrapping-of-the-final-products.pdf
44. https://www.test-toolkit.eu/wp-content/uploads/2019/10/Utilize-recycled-PET-in-production.pdf
45. https://www.plasticseurope.org/en/newsroom/press-releases/archive-press-releases-2018/plastics-2030-voluntary-commitment
46. https://www.plasticseurope.org/application/files/7215/1715/2556/20180116121358-PlasticsEurope_Voluntary_Commitment_16012018_1.pdf
47. https://www.opcleansweep.org
48. They can of course use the RECP methodology to also reduce all of their over-consumption of material and – especially - energy inputs, as well as reduce any type of waste, or air and water pollution, which they generate.
49. https://www.lantech.com/r4/why-stretch-wrapping-is-the-solution-for-unitizing-loads-for-shipment/
50. Ibid.
51. https://www.lantech.com/r2/blog/what-are-the-alternatives-to-stretch-wrap/
52. https://www.lantech.com/r2/blog/can-stretch-wrap-be-recycled/
53. Primary packaging is the material that first envelops the product and holds it. This usually is the smallest unit of distribution or use and is the package which is in direct contact with the contents. Secondary packaging is outside the primary packaging, and may be used to prevent pilferage or to group primary packages together (Wikipedia).
54. https://americanhistory.si.edu/blog/2011/10/food-culture.html

55. https://www.nationalgeographic.com/environment/article/plastic-free-supermarket-grocery-shopping
56. Greenpeace UK, Unpacked: How supermarkets can cut plastic packaging in half by 2025, 2020. https://www.greenpeace.org.uk/wp-content/uploads/2020/08/Greenpeace_Unpacked_Report.pdf
57. https://www.tembopaper.com/news/plastic-straws-and-the-environment-what-is-the-impact#:~:text=In%20the%20US%2C%20an%20estimated,25.3%20billion%20in%20a%20year.
58. https://habitsofwaste.org/call-to-action/plastic-straws-cutlery/#:~:text=The%20average%20person%20uses,and%20thrown%20away%20each%20year.
59. https://www.earthday.org/fact-sheet-single-use-plastics/#:~:text=The%20world%20uses%20500%20billion,Styrofoam%20coffee%20cups%20every%20year.
60. https://pirg.org/resources/10-steps-whole-foods-can-immediately-take-to-reduce-single-use-plastic/#:~:text=Grocery%20stores%2C%20including%20Wegmans%2C%20are,packaging%20and%20reduce%20plastic%20packaging.
61. https://www.greenpeace.org.uk/resources/unpacked-supermarket-plastic-report/
62. This could also be a way of reducing the cost of the final product. According to Greenpeace on average the packaging of fruit and vegetables leads to a 43% increase of the final price. https://francosrl.com/fr/actualites/eliminer-le-plastique-dans-les-rayons-fruits-et-legumes-cest-desormais-possible/
63. https://francosrl.com/fr/actualites/eliminer-le-plastique-dans-les-rayons-fruits-et-legumes-cest-desormais-possible/. Note that this practice has also been criticised for leaving small amounts of residual water on the vegetables, thus increasing their weight, making the customer pay slightly more.
64. Greenpeace has found that bottled water, carbonated drinks and milk bottles are responsible for the most plastic by weight in UK supermarkets. https://www.greenpeace.org.uk/resources/unpacked-supermarket-plastic-report/
65. Information on UK supermarkets: https://www.bbc.com/news/uk-49674153
66. https://www.supermarketnews.com/sustainability/metro-accept-reusable-containers-fresh-food
67. https://www.bbc.com/news/uk-49674153
68. https://www.forgerecycling.co.uk/blog/how-zero-waste-shops-work-a-beginners-guide/#:~:text=Usually%2C%20the%20store%20will%20have,as%20little%20as%20they%20wish.
69. https://www.apeel.com/
70. https://www.sufresca.com/
71. https://www.london.gov.uk/programmes-strategies/environment-and-climate-change/waste-and-recycling/single-use-plastic-bottles/drinking-fountains-london
72. https://www.sciencedirect.com/science/article/abs/pii/S0959652616309519?via%3Dihub
73. https://splosh.com/
74. https://www.britishplastics.co.uk/ materials/procter-gamble-introduce-ds3-clean-products-to-eliminatepla/#:~:text=Procter%20%26%20Gamble%20introduce%20DS3%20Clean%20products%20to%20eliminate%20plastic%20packaging,-by%20Grace%20 Nolan&text=The%20new%20concept%20allows%20consumers,the%20need%20 for%20plastic%20packaging.
75. https://loopstore.com and https://www.greenbiz.com/article/loops-launch-brings-reusable-packaging-worlds-biggest-brands
76. https://ellenmacarthurfoundation.org/explore?contentType=CircularEconomyExample
77. https://www.weforum.org/agenda/2021/04/algramo-reusable-smart-packaging/
78. https://www.alner.id/our-service
79. https://www.siklus.com/
80. Information from National Project Coordinator, UNIDO Ghana office
81. https://education.nationalgeographic.org/resource/sustainable-shoppingwhich-bag-best/
82. Information from National Project Coordinator, UNIDO Ghana office
83. Ellen MacArthur Foundation, Reuse: Rethinking Packaging, 2019
84. UNEP and WRI, Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations, 2019

85. UNEP, “Legal Limits on Single-Use Plastics and Microplastics: A Global Review of National Laws and Regulations”, 2018

86. https://www.bbc.com/news/science-environment-43571269

87. https://www.ipsos.com/en-uk/public-concern-about-plastic-and-packaging-waste-not-backed-willingness-act

88. https://foshbottle.com/blogs/fosh/60-ways-to-reuse-plastic-bottles

89. https://www.ecomasteryproject.com/reuse-plastic-cups/

90. https://www.architectureartdesigns.com/28-creative-ways-to-repurpose-reuse-plastic-spoons/

91. https://www.kiddiebites.com/blogs/news/10-uses-for-your-old-plastic-plates

92. https://unesdoc.unesco.org/ark:/48223/pf0000154093

93. https://en.unesco.org/countries/indonesia

94. C. Bratt, S. Hallstedt, K.-H. Robèrt, G. Broman and J. Oldmark, “Assessment of criteria development for public procurement from a strategic sustainability perspective,” J. of Cleaner Production, vol. 52, pp. 309 – 316, Aug. 2013

95. International Energy Agency estimated the fossil fuel consumption subsidies at $300 billion in 2017 at https://www.iea.org/weo/energysubsidies/

96. Note, however, that separation increases the costs of collection, since the separate streams have to be collected separately. Many schemes balance this cost and benefit by allowing streams which are easily separable (e.g., plastic and metal) to be mixed and collected together.

97. https://www.coresponsibility.com/off-books-informal-recycling-china/

98. https://www.bioenergyconsult.com/recycling-waste-to-energy-saudi-arabia/

99. http://www.engineeringnews.co.za/article/informal-waste-pickers-should-be-integrated-into-formal-waste-management-sector-suggests-analyst-2018-10-17/rep_id:4136. Data is from 2013.

100. file:///C:/Users/Zinaida/Downloads/Emerging-Issues-in-Solid-Waste-Management-in-Argentina.pdf

101. M. Medina, “Scavenger cooperatives in Asia and Latin America”, Resources, Conservation and Recycling, 31, 51-69, 2000. Cited in S. Sasaki, T. Araki, “Employer-employee and buyer-seller relationships among waste pickers at final disposal site in informal recycling: The case of Bantar Gebang in Indonesia” Habitat International 40 51-57, 2013, https://www.researchgate.net/publication/235974002_Employer-employee_and_buyer-seller_relationships_among_waste_pickers_at_final_disposal_site_in_informal_recycling_The_case_of_Bantar_Gebang_in_Indonesia

102. https://www.giz.de/en/downloads/gtz2010-waste-experts-conditions-is-integration.pdf

103. https://digital.detritusjournal.com/articles/in-press/is-there-a-future-for-the-informal-recycling-sector-in-urban-china/162

104. UNEP, Turning off the Tap. How the world can end plastic pollution and create a circular economy, 2023. https://www.unep.org/resources/turning-off-tap-end-plastic-pollution-create-circular-economy

105. South African Department of Environment, Forestry and Fisheries and Department of Science and Innovation, Waste picker integration guideline for South Africa: Building the Recycling Economy and Improving Livelihoods through Integration of the Informal Sector, 2020. https://wasteroadmap.co.za/wp-content/uploads/2021/02/Waste-Picker-Integration-Guidelines.pdf

106. Z. Schyns, M. Shaver, “Mechanical Recycling of Packaging Plastics: A Review”, https://onlinelibrary.wiley.com/doi/full/10.1002/marc.202000415

107. http://www.oecd.org/chemicalsafety/risk-management/global-forum-on-environment-plastics-in-a-circular-economy-meeting-report-.pdf

108. UNEP, Turning off the Tap. How the world can end plastic pollution and create a circular economy, 2023. https://www.unep.org/resources/turning-off-tap-end-plastic-pollution-create-circular-economy

109. https://www.dw.com/en/plastic-waste-and-the-recycling-myth/a-45746469

110. https://wwf.panda.org/wwf_news/?204414

111. https://www.trvst.world/waste-recycling/which-countries-are-best-in-low-zero-waste-management/
112. https://www.henkel.com/press-and-media/press-releases-and-kits/2019-04-29-henkel-integrates-social-plastic-in-packaging-for-beauty-care-and-laundry-home-care-products-936188
113. https://www.petnology.com/online/news-detail/henkel-egypt-and-plastic-bank-stop-over-500-million-plastic-bottles-from-reaching-the-seas
114. https://www.unido.org/sites/default/files/files/2022-01/Plastic_value_chain_in_nigeria.pdf
115. Ibid.
116. PTA: Purified Terephthalic Acid, the main raw material for PET and polyester fibres.
117. J. Harder, "Development status of plastics recycling", https://www.recovery-worldwide.com/en/artikel/development-status-of-plastics-recycling-3801130.html
118. https://www.demeto.eu/project
119. UNIDO, Reducing Plastic Leakage into the Environment in Africa Sustainable alternative materials, innovative packaging and recycling, 2021. https://downloads.unido.org/ot/27/63/27631829/PlasticReportTechnologies-UNIDO-FINAL-20220823-OnePage.pdf
120. https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/chemcycling.html
121. To reach the set targets for reuse and recycling, calculation of targets for each waste stream should be made with a view to collection, recovery, recycling/reuse. Today, in most of the EPR systems calculations of the targets is done only for the 'total' of a product or, in more advanced cases, the mass of materials in a product, without considerations of type and purity of recovered individual materials or type of required technologies for recovery.
122. https://ieep.eu/uploads/articles/attachments/95369718-a733-473b-aa6b-153c1341f581/EPR%20and%20plastics%20report%20IEEP%209%20Nov%202017%20final.pdf?v=63677462324pdf?v=63677462324
123. http://www.oecd.org/environment/waste/policy-highlights-improving-plastics-management.pdf
124. https://www.giz.de/en/downloads/gtz2010-waste-experts-conditions-is-integration.pdf
125. UNEP, "From Pollution to Solution: A global assessment of marine litter and plastic pollution. Synthesis", Nairobi, 2021
126. See, e.g., UNEP, "Global Waste Management Outlook", 2015
127. UNEP, "From Pollution to Solution: A global assessment of marine litter and plastic pollution. Synthesis", Nairobi, 2021
128. M. E. Grigore (2017), Methods of Recycling, Properties and Applications of Recycled Thermoplastic Polymers, Recycling, doi:10.3390/recycling2040024
129. UNEP, "From Pollution to Solution: A global assessment of marine litter and plastic pollution. Synthesis", Nairobi, 2021
130. See, e.g., International Solid Waste Association (ISWA), "Guidelines for Design and Operation of Municipal Solid Waste Landfills in Tropical Climates", 2013
131. Ellen MacArthur Foundation, "The New Plastics Economy: Rethinking the Future of Plastics", 2013
132. https://www.unido.org/sites/default/files/files/2022-01/Plastic_value_chain_in_Egypt.pdf
133. https://www.theoceancleanup.com/
134. http://low-carbon-innovation.org/cleantech-innovation
135. http://salt.nu/wp-content/uploads/2018/11/Komprimert-Report-1021-Feasibility-of-the-PGS-Plastic-Collection-Concept-compressed.pdf

Vienna International Centre
Wagramerstr. 5, P.O. Box 300,
A-1400 Vienna, Austria

+43 1 26026-0

www.unido.org

unido@unido.org

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION