ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ
ΣΧΟΛΗ ΟΙΚΟΝΟΜΙΚΩΝ, ΕΠΙΧΕΙΡΗΜΑΤΙΚΩΝ & ΔΙΕΘΝΩΝ ΣΠΟΥΔΩΝ
ΤΜΗΜΑ ΟΙΚΟΝΟΜΙΚΗΣ ΕΠΙΣΤΗΜΗΣ

ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ «ΒΙΟΟΙΚΟΝΟΜΙΑ, ΚΥΚΛΙΚΗ ΟΙΚΟΝΟΜΙΑ & ΒΙΩΣΙΜΗ ΑΝΑΠΤΥΞΗ»

ΑΝΑΛΥΣΗ ΤΩΝ ΣΤΡΑΤΗΓΙΚΩΝ ΚΥΚΛΙΚΗΣ ΟΙΚΟΝΟΜΙΑΣ ΣΤΗ ΔΙΑΔΙΚΑΣΙΑ ΠΑΡΑΓΩΓΗΣ ΠΛΑΣΤΙΚΩΝ ΜΙΑΣ ΧΡΗΣΗΣ

ΜΑΡΙΝΑ ΛΥΜΑΚΗ

Πειραιάς, Μάρτιος, 2022

UNIVERSITY OF PIRAEUS

SCHOOL OF ECONOMICS, BUSINESS, AND INTERNATIONAL STUDIES

DEPARTMENT OF ECONOMICS

MSc. in Bioeconomy, Circular Economy & Sustainable Development

ANALYZING CIRCULAR ECONOMY STRATEGIES IN THE PRODUCTION PROCESS OF DISPOSABLE PLASTIC

MARINA LYMAKI

Piraeus, Greece, March, 2022

…To one's Resilience

Ανάλυση των στρατηγικών Κυκλικής Οικονομίας στη διαδικασία παραγωγής πλαστικών μιας χρήσης

Σημαντικοί όροι: Βιωσιμότητα, Βιώσιμη παραγωγή, Επιχειρηματικά μοντέλα βιωσιμότητας, Στρατηγικές βιωσιμότητας, Η οικονομία των πλαστικών, Παραγωγή πλαστικών, Μηδενικά απορρίμματα/απόβλητα.

Περίληψη

Η κυκλική οικονομία ολοένα και κερδίζει την προσοχή σε ότι αφορά την ανάπτυξη κοινωνικής και οικονομικής ευημερίας, μειώνοντας ταυτόχρονα την ζήτηση σε πεπερασμένες πρώτες ύλες και ελαχιστοποιώντας τις αρνητικές επιπτώσεις σε διαφορετικούς τομείς όπως περιβάλλον κλπ. Η μετάβαση αυτή απαιτεί μια συστημική προσέγγιση η οποία θα βοηθήσει σε βελτιώσεις του υπάρχοντος συστήματος καθώς επίσης θα δημιουργήσει και νέους μηχανισμούς συνεργασιών μεταξύ θεσμών. Στον ιδιωτικό τομέα οι επιχειρήσεις έρχονται αντιμέτωπες με την πρόκληση και ευκαιρία να επεκτείνουν τις δραστηριότητες τους και να δημιουργήσουν αξία μεταξύ αλυσίδων προμηθειών πρώτων υλών που παρουσιάζουν ελλείψεις και εγείρουν θέματα περιβαλλοντικών επιπτώσεων οδηγώντας κατά συνέπεια σε αύξηση τιμών και αβεβαιότητα. Το επιχειρηματικό μοντέλο κυκλικής οικονομίας θα συνεισφέρει στην απεξάρτηση ανάπτυξης από την εκμετάλλευση πόρων που τείνουν να εκλείψουν, και θα επιτρέψει την οικονομική ανάπτυξη μεταξύ ορίων φυσικών πόρων. Με τον τρόπο αυτό οι επιχειρήσεις θα έχουν την ευκαιρία να καινοτομήσουν επιτυγχάνοντας την βέλτιστη απόδοση προϊόντων και υπηρεσιών με τους ελάχιστους πόρους. Μια από τις κύριες προκλήσεις της μετάβασης στο οικονομικό μοντέλο κυκλικής οικονομίας είναι η εφαρμογή στρατηγικών κυκλικότητας στην βιομηχανία των πλαστικών. Η νέα οικονομία των πλαστικών σκοπεύει να ξεπεράσει τους περιορισμούς που θέτονται από μη οργανωμένες και σταδιακές πρωτοβουλίες μεταξύ ενδιαφερόμενων μερών. Σκοπός είναι να δημιουργήσει τις κατάλληλες κατευθυντήριες για την δημιουργία καινοτομίας και μετάβαση των αλυσίδων αξίας προς την μεγιστοποίηση οικονομικού κέρδους αλλά και βέλτιστων περιβαλλοντικών αποτελεσμάτων.

Οι δυσκολίες αλλά και οι ευκαιρίες που προκύπτουν από τον σημερινό κύκλο ζωής των πλαστικών απαιτούν δραστικές αλλαγές στις οποίες η έρευνα και καινοτομία καθώς επίσης και η εφαρμογή των κατάλληλων θεσμικών πλαισίων, παίζουν καθοριστικό ρόλο. Ενώ τα πλαστικά αποτελούν ένα χρηστικό υλικό στο σημερινό σύστημα υπάρχουν σημαντικά μειονεκτήματα μεταξύ των οποίων οικονομικές απώλειες αξίας των υλικών, και περιβαλλοντικών επιπτώσεων. Είναι πλέον προφανές ότι η οικονομία των πλαστικών πρέπει να αλλάξει από ένα σύστημα που παράγει απορρίμματα βάση σχεδιασμού σε ένα σύστημα που διατηρεί στο μέγιστο την αξία και τα πλεονεκτήματα των πλαστικών. Η μακροπρόθεσμη λύση προς την επίτευξη της αλλαγής αυτής είναι μέσω πρωτοβουλιών καινοτομίας και έρευνας σε συνδυασμό με χάραξη πολιτικών που θα συνεισφέρουν αποτελεσματικά.

Analyzing Circular Economy strategies in the production process of disposable plastic

Keywords: Sustainability, Circular economy, zero waste, Plastics Economy, Sustainable production, Sustainability business models, Sustainability strategy, Plastics production

Abstract

The circular economy is gaining growing attention as a potential way for our society to increase prosperity, while reducing demands on finite raw materials and minimizing negative externalities. Such a transition requires a systemic approach, which will leverage improvements to the existing model as well as develop new collaboration mechanisms. In the private sector companies face a rapidly increasing challenge, and opportunity, to grow their businesses and create value amidst volatile and scarce supply of natural resources and environmental concerns, driving up prices and uncertainty. The circular economy business model will leverage the decoupling of growth from scarce resource use, allowing economic development within natural resource limits and allowing companies to innovate to enable customers and users to do 'more with less'. One of the main challenges of the circular economy transition is the implementation of circular strategies in the single-use Plastics industry. The New Plastics Economy aims to overcome the limitations of today's incremental improvements and fragmented initiatives, to create a shared sense of direction, to spark a wave of innovation and to move the plastics value chain into a positive spiral of value capture, stronger economics, and better environmental outcomes. The challenges and opportunities posed by the current plastics system demand fundamental change in which research and innovation (R&I), enabled and reinforced by policymaking, play a crucial role. While plastics bring benefits as a functional material, the current system has significant drawbacks, including economic loss of material value and environmental damage. It has become evident that the plastics economy needs to change from a system that produces waste by design to one that preserves the value and benefits of plastics. This can be achieved by systemic change initiatives powered by R&I and enabled through policymaking is the only long term solution.

Table of Contents

Περίληψη vii

Abstract ix

Table of Contents xi

Table of Figures xiii

INTRODUCTION 2

1. CIRCULAR ECONOMY TRANSITION 4

1.1 The "Business as usual" impacts 6

1.2 Circular economy transition for economic growth 10

1.3 The "Circular Advantage" 13

1.4 Circular economy business models 15

2. EUROPE TOWARDS CIRCULAR ECONOMY 18

3. CIRCULAR ECONOMY IN PRODUCTION-Closing the Loop 22

4. ZERO WASTE AND CIRCULAR ECONOMY 24

4.1 Zero waste business model 24

4.2 Zero waste Hierarchy 25

5. PLASTICS PRODUCTION (Single-Use) AND CIRCULAR ECONOMY 28

5.1 Plastics Waste management 31

5.2 The New Plastics (Circular) Economy 33

6. CIRCULAR ECONOMY STRATEGIES FOR SINGLE USE PLASTICS 36

6.1 COLLECTION AND SHORTING 39

6.2 MECHANICAL RECYCLING 43

6.3 CHEMICAL RECYCLING 45

CONCLUSIONS 50

Bibliography 52

Table of Figures

Figure 1- Around the world, the link between increased resource use and growth 4

Figure 2 -After the year 2000, a new trend in the growth and resource use dynamic can be seen. 5

Figure 3-The Nine planetary boundaries. 9

Figure 4- The widening gap between sustainable resource availability and demand. 10

Figure 5 – Linear Economy vs Circular economy. 11

Figure 6-Overview of circular economy. 12

Figure 7- Value areas of circular economy opportunity. 14

Figure 8-The five circular business models. 15

Figure 9- The Circular Economy Action Plan 2020 as part of the EU Green Deal and mutual synergies. 18

Figure 10-Zero waste hierarchy inverted Pyramid. 26

Figure 11-The two main categories of plastics and their single-use applications. 28

Figure 12-Plastics replacing the traditionally used materials. 29

Figure 13-Global plastic production by industrial sector, 2015. 30

Figure 14-Distribution of single-use plastic production by region (2014). 30

Figure 15- Plastics waste infographics. 31

Figure 16- Jourvey of products at end of life. 32

Figure 17- Disposal of all plastic waste ever generated (as of 2015). 33

Figure 18 - Waste management hierarchy 33

Figure 19- Ambitions of the New Plastics Economy. 34

Figure 20- Overview of the global plastic supply chain. 36

Figure 21- Plastic-related risk assessment across the value chain. 37

Figure 22- Overview of Recycling types. 38

Figure 23-Overview of European plastic streams. 42

Figure 24- Overview of different loops for plastics in a circular economy. 46

INTRODUCTION

The circular economy is a novel economy model gaining growing attention as a potential way for our society to increase prosperity and at the same time reduce demands on finite raw materials. To achieve such a transition systemic approach is needed. Incremental improvements on the existing model must be accelerated and new collaboration mechanisms must be developed. The growth model of economies globally and of companies for the past 250 years was based on the availability of plentiful and inexpensive natural resources and is no longer a sustainable option and for the last two decades plentiful research and practical experience has made effort in justifying the need for a new economy model transition. When resources are abundant and inexpensive and the impact on the environment is not taken into consideration, the current "linear" approach to satisfying demand can be very successful. Companies are able, with ever-increasing efficiency, to extract raw materials, use those materials as inputs to the manufacturing of desired products, and sell and ship those products to as many customers as possible that use and discard them after the products have served their purpose. Put in shorthand, an economy built on the principles of "take, make, and waste". The transition to a circular economy represents a fundamental shift in the development of business and economic opportunities. There is a clear business case to support the circular economy transition as manufacturing firms in the European Union for example spend 40% of total costs on materials and processing and some estimates anticipate cost savings of €600 billion a year and €1.8 trillion more in other economic benefits.

One of the leading materials in our society and modern economy is Plastics, combining unrivalled functional properties with low cost. Their use has exponentially increased in the past half-century and is expected to double again in the next 20 years. In our society we are in contact with plastics especially plastic packaging and disposable consumer goods daily. While delivering many benefits, the current plastics business has drawbacks that are becoming more apparent by the day. The need for 'New Plastics Economy' is increasing to capture these opportunities, offering a more sustainable future, aligned with the Sustainable development goals set by the UN and principles of the circular economy. The New Plastics Economy has a systemic and collaborative approach with the aim to overcome the limitations of today's incremental improvements and unify fragmented initiatives. Circular economy business models and strategies in the production of plastics can alter the current system's unsustainable future, leverage new value chain creation, and enable sustainable growth.

1. CIRCULAR ECONOMY TRANSITION

Natural living systems allow resources to return to the environment through processes of energy flows and nutrient cycles. With the advent of industrialization, these systems began to shift away from this sustainable lifecycle. Up to now businesses have adopted the Linear Economy model based on the sequence take (raw material), make (products), use (consume), dispose (of non-recyclable waste), a model proven to be unsustainable for both its resources consumption and its environmental impact. Raw materials are collected, and then transformed into products that are used until they are finally discarded as waste. Value is created in this economic system by producing and selling as many products as possible regardless of resource availability which in some cases is quaintly considered to be abundant. The excessive consumption rates based on products and services according to the linear model will inevitably lead to natural resources depletion and non-reversible environmental degradation.

The world is already using approximately one and a half of the planet's worth in resources every year. It's an unsustainable scenario, especially given the lack of disruptive innovations on the horizon that can scale quickly enough to change the trajectory. According to economic analysis there is a strong relationship between resource consumption and GDP as illustrated on *Figure.1*. Historically for every 1 percent increase in GDP, resource usage has risen on average 0.4 percent. This means population and economic growth are key drivers of resource demand.

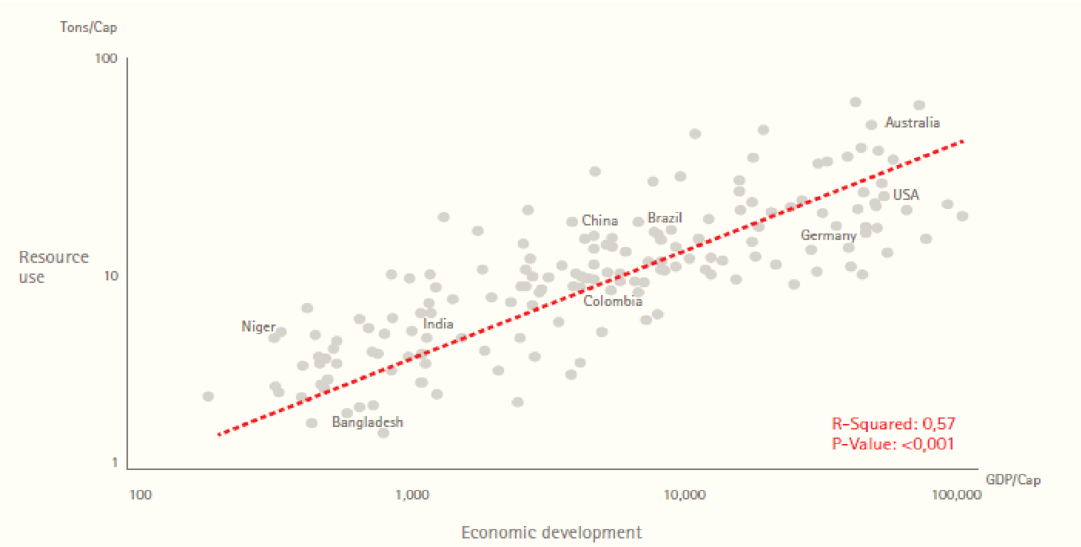


Figure 1- Around the world, the link between increased resource use and growth

Source: P. Lacy et al.*, 'Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth',* Accenture Strategy*, p. 24, 2014.*

Fortunately, commodity prices have been historically inversely related to growth. Costs declined automatically. But around 2000 this relationship reversed, making reliance on resources for growth increasingly unattractive (*Figure.2*). As a growing population and expanding global middle class drive demand for resources, these trends will continue and ultimately threaten continuation of business as usual.

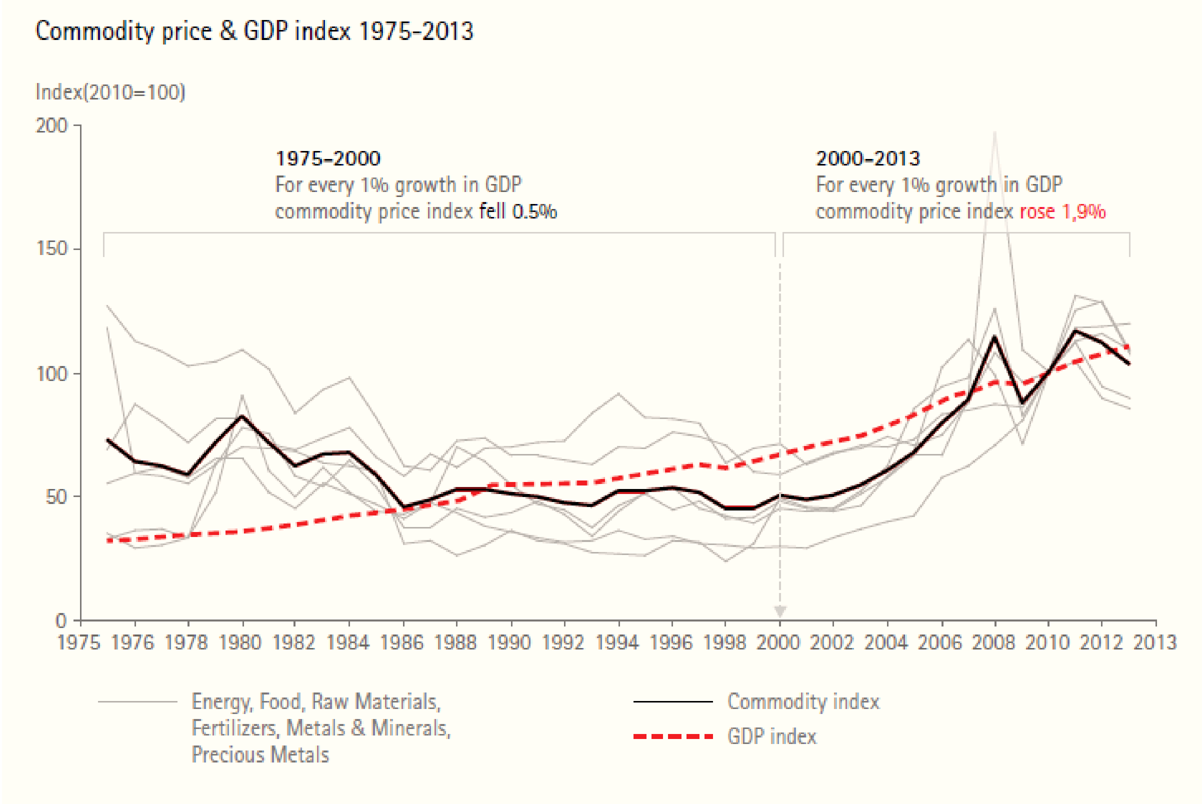


Figure 2 -After the year 2000, a new trend in the growth and resource use dynamic can be seen.

Source: P. Lacy et al.*, 'Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth',* Accenture Strategy*, p. 24, 2014.*

We are rapidly approaching a point at which the linear model is no longer viable. Due to rising global affluence, the availability of many non-renewables (including metals, minerals, and fossil fuel) cannot keep up with demand, the regenerative capacity of renewables (such as land, forests, water) becomes strained to its limits, and the planetary boundaries become threatened as never before. As shown by the IPCC2[1], US National Climate Assessment[2], and many others, negative effects of the current growth model are already being reported on all continents. Unless current trends are reversed, resource supply disruptions coupled with rising and increasingly volatile prices will in the next two decades translate into trillion-dollar losses for companies and countries whose growth remains tied to the use of scarce and virgin natural resources. Businesses upon deciding and setting their direction, are aware that continued dependence on scarce natural resources for growth exposes a company's tangible and intangible value to serious risks as described below.

a) Revenue reduction: Supply uncertainties and changing consumer preferences could prevent companies from generating revenues and maintaining market share. For instance, companies that depend heavily on scarce resources might have to shut down production at times and be unable to deliver demanded volumes.
b) Cost increases: Companies whose growth is tightly tied to scarce resources will find themselves at a competitive disadvantage due to rising and volatile prices that reduce their ability to forecast and compete with less resource-intensive competitors.
c) Intangible assets: A company's environmental footprint and resource dependence could erode brand value as consumers shun companies with unsustainable business practices. And, as planetary bottlenecks and resource scarcity become more critical, policymakers likely will favor companies that can prove they have positive societal impact and can operate without depleting the country's natural resources.

1.1 The "Business as usual" impacts

Excessive and unsound use of natural resources will inevitably lead to various environmental problems. Soil degradation, water acidification, air pollution, waste generation and carbon emissions, are amongst others. These are leading to a transgression of the nine key planetary boundaries.

The planetary boundaries were established by director Johan Rockström[3] who led a group of 28 internationally renowned scientists to identify the nine processes that regulate the stability and resilience of the Earth system. The result of this summit was to propose quantitative planetary boundaries within which humanity can continue to develop and thrive for generations to come.

---

[1] Source: https://www.ipcc.ch/working-group/wg2/

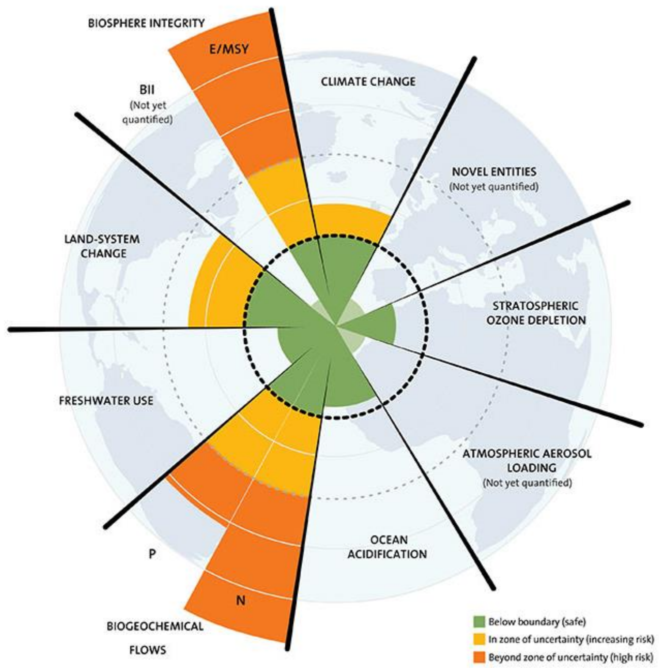
[2] Source: https://www.c2es.org/content/national-climate-assessment/

[3] Johan Rockström is Director of the Potsdam Institute for Climate Impact Research and Professor in Earth System Science at the University of Potsdam. Source: https://www.pik-potsdam.de/members/johanro

Crossing these boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes. The planetary boundaries framework has generated enormous interest within science, policy, and practice. The nine planetary boundaries are (Figure.3):

1. *Atmospheric Aerosol Loading – Particle Pollution*: Although not yet quantified, though aerosol particles that enter our atmosphere can be very damaging to human health. The boundary was proposed primarily because of the influence of aerosols on Earth's climate system. Through their interaction with water vapor, aerosols play a critically important role in our water cycles, affecting cloud formation and global / regional patterns of atmospheric circulation, such as the monsoon systems in tropical regions. They also have a direct effect on climate, by changing how much solar radiation is reflected or absorbed in the atmosphere.
2. *Biochemical Flows – Nitrogen and Phosphorus*: Nitrogen and phosphorus are both essential elements for plant growth, so fertilizer production and application is the main concern. Human activities now convert more atmospheric nitrogen into reactive forms than all the Earth's terrestrial processes combined. Much of this new reactive nitrogen is emitted to the atmosphere in various forms rather than taken up by crops. When it is rained out, it pollutes waterways and coastal zones, a threshold we are already crossing.
3. *Land System Change:* Forests, grasslands, wet-Lands, and other vegetation types are primarily being converted to agricultural land by humans. This activity is undoubtedly behind the serious reductions in biodiversity, and it impacts on water flows and on the biogeochemical cycling of carbon, nitrogen and phosphorus and other important elements. Scientists say that a boundary for human changes to land systems needs to reflect not just the absolute quantity of land, but also its function, quality, and spatial distribution.
4. *Freshwater Use*: The consequences of human modification of water bodies include both global-scale river flow changes and shifts in vapor flows arising from land use change. These shifts in the hydrological system can be abrupt and irreversible. Water is becoming increasingly scarce – by 2050 about half a billion people are likely to be subject to water-stress.
5. *Ocean Acidification*: 25% of the CO2 that humans emit into the atmosphere is ultimately dissolved in the oceans. Here it forms carbonic acid, altering ocean chemistry and decreasing the pH of the surface water. Beyond a threshold concentration, this rising acidity makes it hard for organisms such as corals and some shellfish and plankton species to grow and survive and losing various species would greatly impact on marine ecosystems. CO2 concentration is the underlying controlling variable for both the climate and the ocean acidification boundaries.

6. *Climate Change*: We have sadly already passed this planetary boundary due to the levels of CO2 in the atmosphere. We are already losing summer polar sea-ice, and weakening carbon sinks, so really the question now is: how long we can remain over this boundary before large, irreversible changes become unavoidable?
7. *Novel Entities – Chemical Pollution*: Emissions of toxic and long-lived substances such as synthetic organic pollutants, heavy metal compounds and radioactive materials represent some of the key human-driven changes to the planetary environment. These compounds can have potentially irreversible effects on living organisms and on the physical environment. At present, we are unable to quantify a single chemical pollution boundary, although the risk of crossing Earth system thresholds is considered sufficiently well-defined for it to be included in the list.
8. *Biosphere Integrity – Biodiversity Loss:* The demand for food, water and resources are the main drivers for change. The current high rates of ecosystem damage and extinction can be slowed by efforts to protect the integrity of living systems (the biosphere), enhancing habitat, and improving connectivity between ecosystems while maintaining the high agricultural productivity that humanity needs.
9. *Ozone Depletion*: The stratospheric ozone layer in the atmosphere filters out ultraviolet (UV) radiation from the sun. If this layer decreases, increasing amounts of UV radiation will reach ground level. This can cause a higher incidence of skin cancer in humans as well as damage to terrestrial and marine biological systems. Fortunately, because of the actions taken because of the Montreal Protocol, we appear to be on the path that will allow us to stay within this boundary.



Credit: Designed by Azote for Stockholm Resilience Centre, based on analysis in Persson et al 2022 and Steffen et al 2015.

Figure 3-The Nine planetary boundaries.

Source: https://www.stockholmresilience.org/research/planetary-boundaries/the-nine-planetary-boundaries.html

We've passed three already rates of biodiversity loss, climate change, and human interference with the nitrogen cycle, threatening abrupt or irreversible environmental changes that can have far reaching social and economic consequences. If nothing is done to address the current natural resources exploitation sustainability issue that is connected to the planetary boundaries progress, the economic impact of resource scarcity on this scale would be devastating (Figure.4).

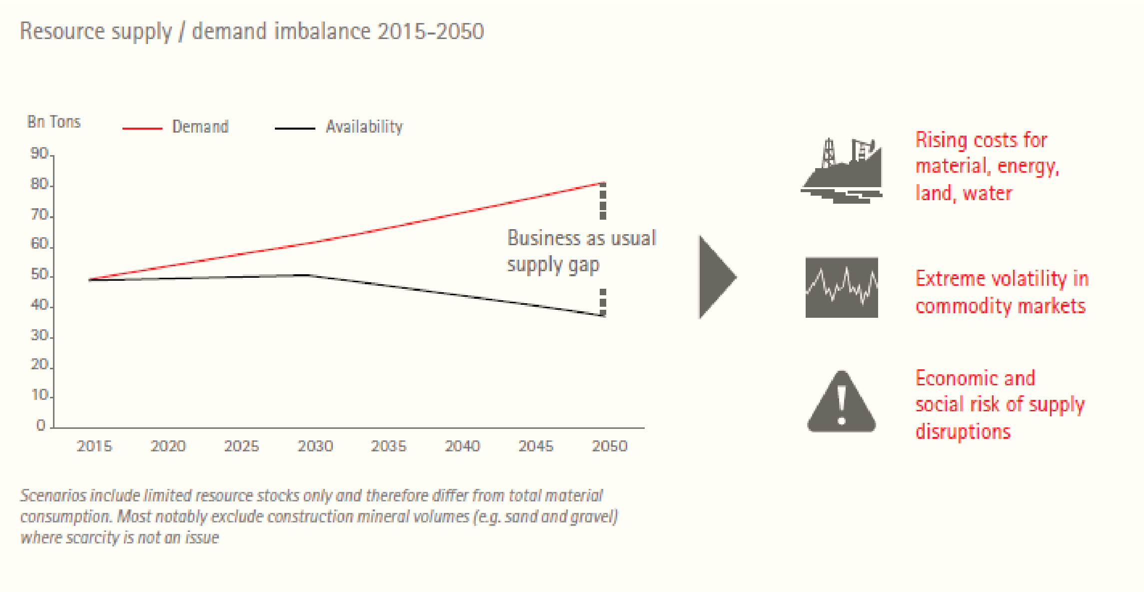


Figure 4- The widening gap between sustainable resource availability and demand.

Source: P. Lacy et al.*, 'Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth',* Accenture Strategy*, p. 24, 2014.*

1.2 Circular economy transition for economic growth

Circular economy is a new sustainable model for economic growth and introduces a different approach of production and consumption. There are various definitions for the circular economy approach, the predominant definition comes from the *Ellen MacArthur Foundation* according to which:

"Circular economy is an industrial system that is restorative and regenerative by design. It rests on three main principles: preserving and enhancing natural capital, optimizing resource yields and fostering system effectiveness (Ellen MacArthur Foundation, 2017)[4]".

The circular economy model aims to keep the added value of products for as long as possible and eliminate waste, by keeping resources within the economy once a product has reached it lifecycle end to be used again and again creating further value. The better the integrity of the product is preserved; the more value is retained as opposed to the linear model (Figure.5).

[4] https://ellenmacarthurfoundation.org/publications

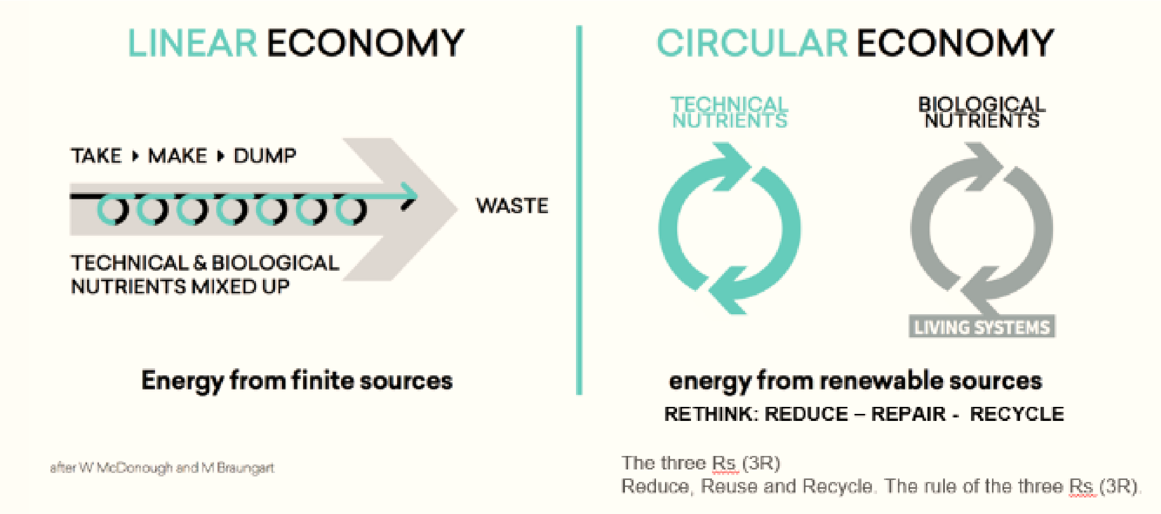


Figure 5 – Linear Economy vs Circular economy.

Source: https://sustainabilityguide.eu/sustainability/circular-economy/

These basic principles provide a framework that brings together methods and approaches drawn from different sources like cradle-to-cradle, biomimicry, industrial symbiosis, ecosystem services and more. The shift is a challenge, but it also brings new opportunities in infrastructure, energy, and production in their adaption to fit the circular economy model. Some business models are easier than others to begin with, such as the leasing of products instead of buying (everything from jeans to trucks), companies which collect and renovate their own products and then sell them in the store in a separate department or peer-to-peer models. Companies will find new ways to extend the life of products or components, to find value in the waste, or the design of circular use. Therefore, transition to a more circular economy requires changes throughout value chains, from product design to new business and market models, from new ways of turning waste into a resource to new modes of consumer behavior. This implies full systemic change, and innovation not only in technologies, but also in organization, society, finance methods and policies (Figure.6).

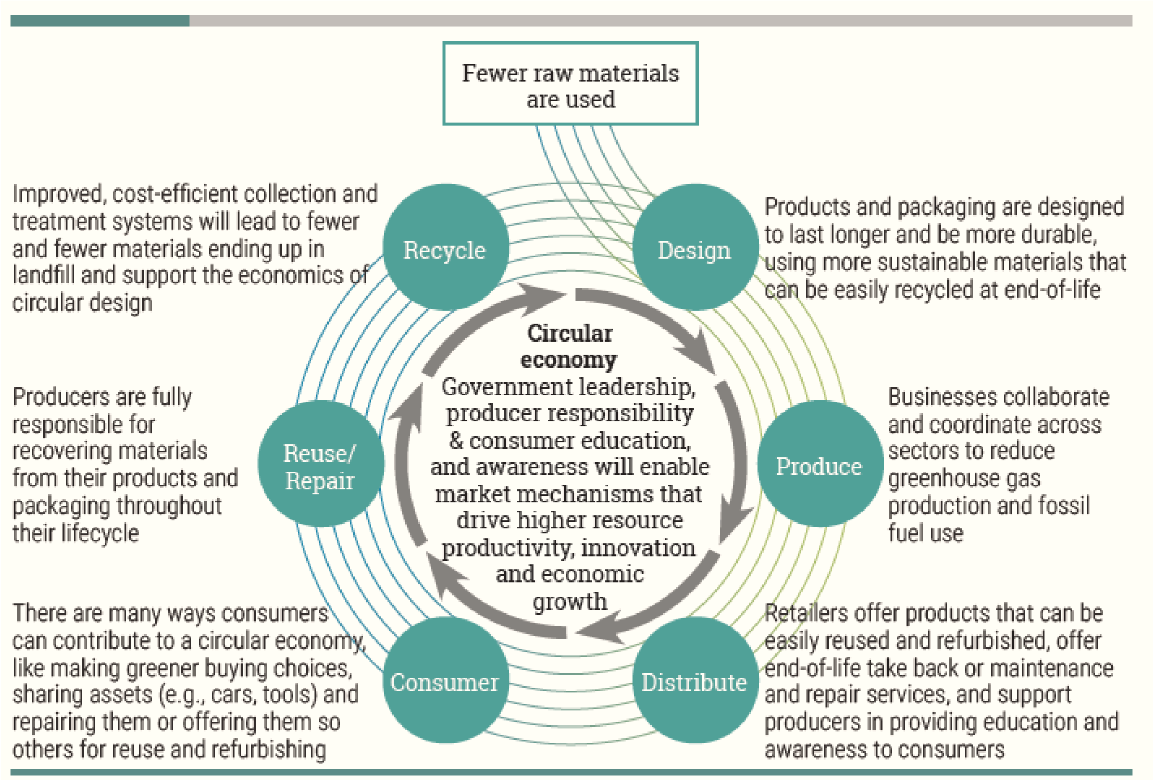


Figure 6-Overview of circular economy.

Source: 2017 strategy for a waste-free Ontario. Building the circular economy. https://www.ontario.ca/page/strategy-waste-free-ontario-building-circular-economy

Even in a highly circular economy there will remain some element of linearity as virgin resources are required, and residual waste is disposed of. Circular economy approaches 'design out' waste and typically involves innovation throughout the value chain, rather than relying solely on solutions at the end of life of a product. For example, they may include:

- Reducing the quantity of materials required to deliver a particular service (light-weighting);
- Lengthen products' useful life (durability);
- Reducing the use of energy and materials in production and use phases (efficiency);
- Reducing the use of materials that are hazardous or difficult to recycle in products and production processes (substitution);
- Creating markets for secondary raw materials (recyclates) (based on standards, public procurement, etc.);

- Designing products that are easier to maintain, repair, upgrade, remanufacture or recycle (Eco design[5]);
- Developing the necessary services for consumers in this regard (maintenance/repair services, etc.);
- Incentivizing and supporting waste reduction and high-quality separation by consumers;
- Incentivizing separation, collection systems that minimize the costs of recycling, and reuse;
- Facilitating the clustering of activities to prevent by-products from becoming wastes (industrial symbiosis);
- Encouraging wider and better consumer choice through renting, lending or sharing services as an alternative to owning products, while safeguarding consumer interests (in terms of costs, protection, information, contract terms, insurance aspects, etc.);

1.3 The "Circular Advantage"

In circular economy, growth is decoupled from the use of scarce resources through disruptive technology and business models based on longevity, renewability, reuse, repair, upgrade, refurbishment, capacity sharing, and dematerialization. Companies no longer focus mainly on driving more volume and squeezing out cost through greater efficiency in supply chains, factories, and operations. Rather, they concentrate on rethinking products and service from the bottom up to "future proof" their operations to prepare for inevitable resource constraints all the way through to the customer value proposition. This implies eliminating waste, creating step changes in resource productivity and at the same time enhancing the customer value proposition on dimensions such as price, quality, and availability.

By design, circular economy models require companies to become highly involved in the use and disposal of products, finding ways to move revenue generation from selling the physical stuff to providing access to it and/or optimizing its performance along the entire value chain. Once a business goes circular, every aspect of it must be configured with the use and return in mind in addition to production and selling. In this sense the circular economy brings about a massive re-alignment of customer and business incentives – no more intentionally designing products to break down, for obsolescence or disregarding externalities. Pioneering innovators have realized the circular

[5] **The integration of environmental aspects into the product development process, by balancing ecological and economic requirements. Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle. Source: https://www.eea.europa.eu/help/glossary/eea-glossary/eco-design**

economy is not only about resource supply and use efficiency, but indeed even more about evolving their business models to transform the nature of resource demand from the customer's point of view, as in the case of the power tool. Research has identified more than 100 truly disruptive companies applying circular economy thinking and new technology to transform in ways that seriously threaten incumbents. The competitive edge these companies gain could be mentioned as the "circular advantage". The circular advantage comes through innovating for both resource efficiency and customer value—delivering at the heart of a company's strategy, technology, and operations.

The overall value of the circular economy often has diverging results. Across the studies, however, there has been the conclusion that the circular economy has the potential to become a trillion-dollar opportunity globally soon. For the global economy, the full set of circular economy approaches can add over five times the value of current best estimates by 2030 by reducing resource constraints to growth. This value is divided into four broad areas as mentioned bellow on Figure.7.

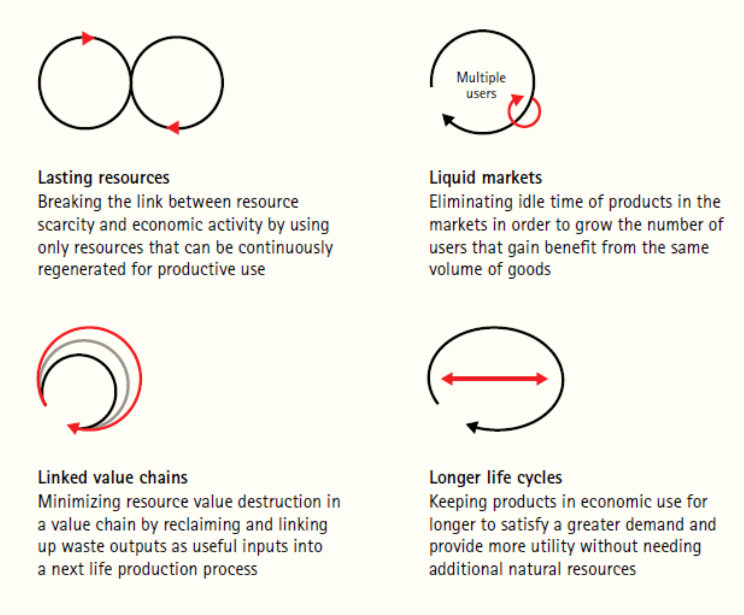


Figure 7- Value areas of circular economy opportunity.

Source: P. Lacy et al.*, 'Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth',* Accenture Strategy*, p. 24, 2014.*

1. *Lasting resources* that can be continuously regenerated over time to not only last longer (efficiency) but last forever (effectiveness) (e.g., renewable energy and biochemicals).
2. *Liquid markets* where products and assets are optimally utilized by becoming easily accessible and convertible between users (e.g., sharing / trading idle product and asset capacity).

3. *Long life cycles* where products are made to last (e.g., monetizing product longevity through service, upgrade, and remanufacturing).
4. *Linked value chains* where zero waste is generated from production to disposal (e.g., boosting recycling and resource efficiency).

1.4 Circular economy business models

At a conceptual level, there is a strong and intuitive business case behind the circular economy. Companies want to reduce their dependence on increasingly scarce and costly natural resources while turning waste into additional revenue and value and sharpening their customer insight and value proposition. So far, their strategies, structures and operations are deeply rooted in the linear approach to growth. Companies seeking the circular advantage will need to develop business models that are free of the constraints of linear thinking. These models are about driving positive impact 'through growth'. Among today companies we could identify five underlying business models that are generating resource productivity improvements in innovative ways (Figure.8).

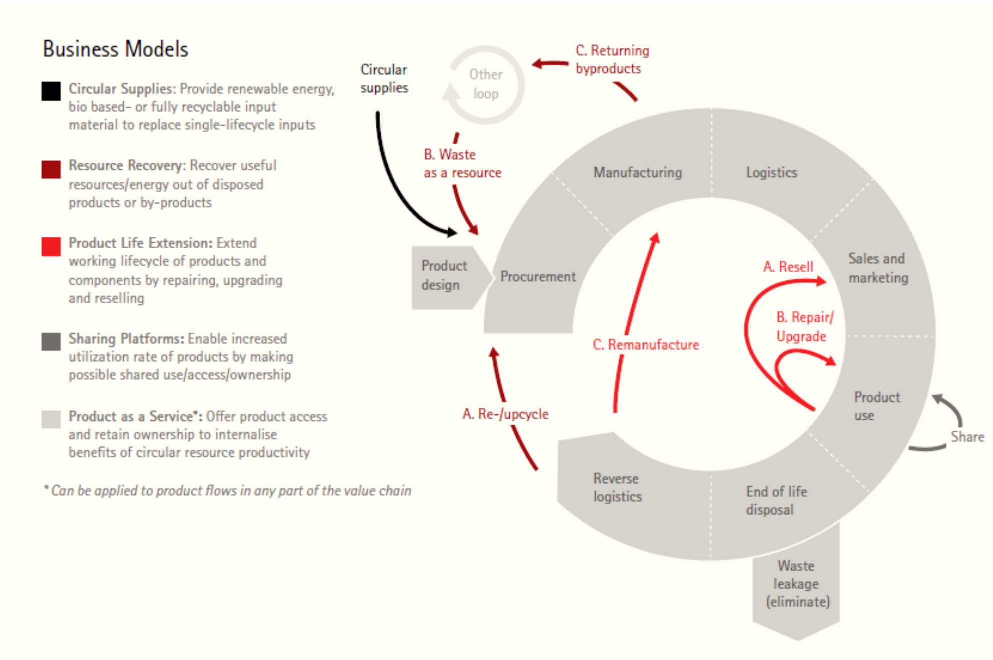


Figure 8-The five circular business models.

Source: P. Lacy et al.*, 'Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth',* Accenture Strategy*, p. 24, 2014.*

i. Circular Supplies

The Circular Supplies business model is based on supplying fully renewable, recyclable, or biodegradable resource inputs that underpin circular production and consumption systems. Companies in this model replace linear resource approaches and phase out the use of scarce resources while cutting waste and removing inefficiencies. This model is most powerful for companies dealing with scarce commodities or ones with a major environmental footprint.

ii. Resource Recovery

Recovery of embedded value at the end of one product lifecycle to feed into another promotes return chains and transforms waste into value through innovative recycling and upcycling services. Having its bedrock in traditional recycling markets this business model leverage new technologies and capabilities to recover almost any type of resource output at a level of value equivalent to, or even above, that of the initial investment. Solutions range from industrial symbiosis[6] to integrated closed loops recycling and Cradle-to-Cradle[7] designs where disposed products can be reprocessed into new. This model, which enables a company to eliminate material leakage and maximize economic value of product return flows, is a good fit for companies that produce large volumes of by-product or where waste material from products can be reclaimed and reprocessed cost effectively.

iii. Product Life Extension

Product Life Extension allows companies to extend the lifecycle of products and assets. Values that would otherwise be lost through wasted materials are instead maintained or even improved by repairing, upgrading, remanufacturing or remarketing products. Additional revenue is generated thanks to extended usage. Using this model, a company can help ensure that products stay economically useful for as long as possible and that product upgrades are done in a more targeted way (for instance, an outdated component is replaced instead of the entire product). This model is appropriate for most capital-intensive B2B segments (such as industrial equipment) and B2C companies that serve markets where used products (or "recommerce") are common or whose new releases of a product typically generate only partial additional performance benefits for customers over the previous version.

---

[6] Industrial symbiosis is the process by which wastes or by-products of an industry or industrial process become the raw materials for another. Application of this concept allows materials to be used in a more sustainable way and contributes to the creation of a circular economy. Source: https://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2018/05/Industrial_Symbiosis.pdf

[7] The Cradle to Cradle® design framework is inspired by nature: The aim is not only to minimise negative influences but also to leave a positive ecological footprint. As a result, products, processes, buildings and cities will emerge which are safe for humans, healthy for the environment and successful for business. Source: https://epea.com/en/about-us/cradle-to-cradle

iv. Sharing Platforms

The Sharing Platforms business model promotes a platform for collaboration among product users, either individuals or organizations. These facilitate the sharing of overcapacity or underutilization, increasing productivity and user value creation. This model, which helps maximize utilization, could benefit companies whose products and assets have a low utilization or ownership rate. However, today it's most found among companies specializing in increasing the utilization rate of products without doing any manufacturing themselves, putting considerable stress on traditional manufacturers.

v. Product as a Service

The Product as a Service business model provides an alternative to the traditional model of "buy and own." Products are used by one or many customers through a lease or pay-for-use arrangement. This business model turns incentives for product durability and upgradability upside down, shifting them from volume to performance. With a Product as a Service business model, product longevity, reusability, and sharing are no longer seen as cannibalization risks, but instead, drivers of revenues and reduced costs. This model would be attractive to companies whose products' cost of operation share is high and that have a skill advantage relative to their customers in managing maintenance of products (giving them an edge in selling services and recapturing residual value at end of life).

2. EUROPE TOWARDS CIRCULAR ECONOMY

The European Union introduced its vision of the circular economy from 2014. The Circular Economy Action Plan 2020 (CEAP) [8]seeks to enhance the EU Green Deal[9] by providing businesses with a trigger to scale up the circular economy (Figure.9).

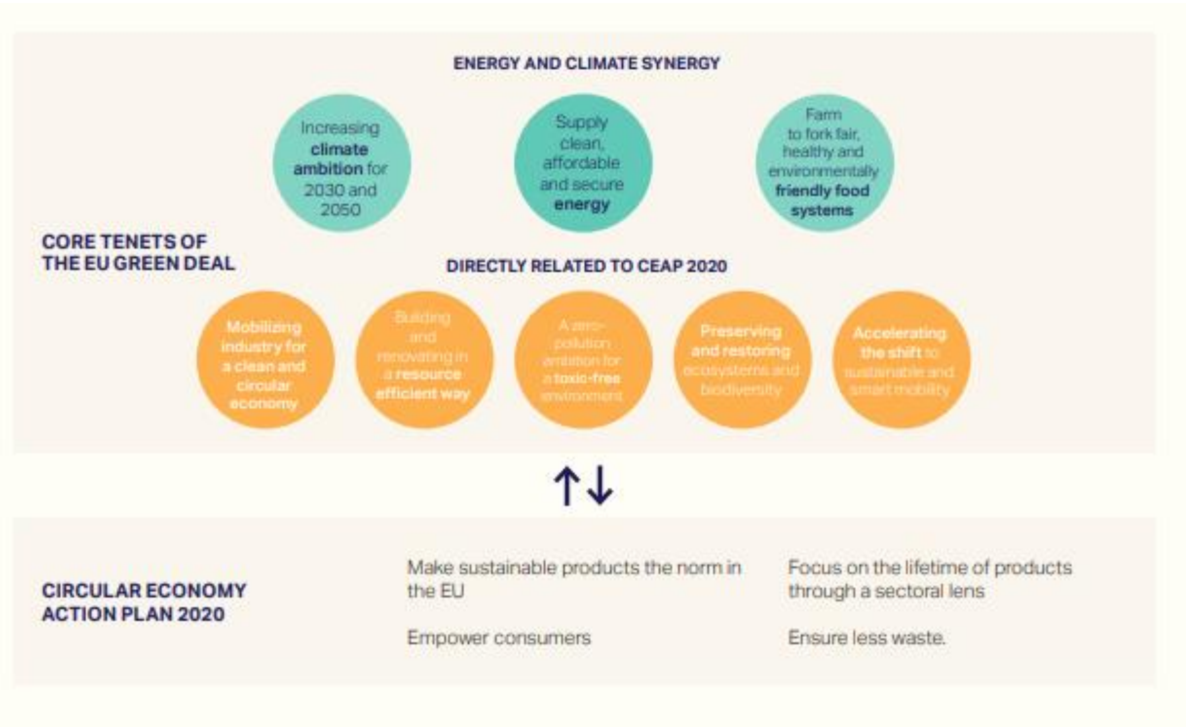


Figure 9- The Circular Economy Action Plan 2020 as part of the EU Green Deal and mutual synergies. Source:https://docs.wbcsd.org/2020/11/WBCSD_Circular_Economy_Action_Plan_2020%E2%80%93Summary_for_business.pdf

The four core themes of the Circular Economy Action Plan 2020 are:

- Make sustainable products.
- Empower consumers.
- Focus on the lifetime of products through a sectoral lens.
- Ensure less waste.

A recent study estimates that applying circular economy principles across the EU economy has the potential to increase EU GDP by an additional 0.5% by 2030 creating around 700 000 new jobs. There

---

8 Source: https://docs.wbcsd.org/2020/11/WBCSD_Circular_Economy_Action_Plan_2020%E2%80%93Summary_for_business.pdf

9 The "Green Deal" is the EU's new growth strategy that aims to transform the EU into a competitive economy, where economic growth is decoupled from resource use.

is a clear business case for individual companies as well. Manufacturing firms in the EU spend on average about 40% on materials, closed loop models can increase their profitability, while sheltering them from resource price fluctuations. The circular economy can strengthen the EU's industrial base and foster business creation and entrepreneurship among SMEs through. Innovative models based on a closer relationship with customers, mass customization, the sharing and collaborative economy, and powered by digital technologies, such as the internet of things, big data, block chain and artificial intelligence, will not only accelerate circularity but also the dematerialization of our economy and make Europe less dependent on primary materials. The intention is to create an efficient framework regarding products and policies that will encourage the sustainable products market, companies to adopt sustainable business models and finally change the consuming patterns and generate less or even no waste during production. Of course, all these changes must take place progressively following key product value chain priority implementation. As part of the governance of the sectorial actions, the Commission will cooperate closely with stakeholders in key value chains to identify barriers to the expansion of markets for circular products and ways to address those barriers. The industry sectors this action will take place include the following:

i. *Electronics and ICT*

'Circular Electronics Initiative' mobilizing existing and new instruments. In line with the new sustainable products policy framework, this initiative will promote longer product lifetimes and include, among others, the following actions:

- *Regulatory measures* for electronics and ICT including mobile phones, tablets and laptops under the Eco-design Directive so that devices are designed for energy efficiency and durability, reparability, upgradability, maintenance, reuse and recycling.
- *Focus on electronics and ICT as a priority sector* for implementing the 'right to repair', including a right to update obsolete software.
- *Regulatory measures* on chargers for mobile phones and similar devices, including the introduction of a common charger, improving the durability of charging cables, and incentives to decouple the purchase of chargers from the purchase of new devices.
- *Improving the collection and treatment of waste* electrical and electronic equipment including by exploring options for an EU-wide take back scheme to return or sell back old mobile phones, tablets and chargers.

- *Review of EU rules* on restrictions of hazardous substances in electrical and electronic equipment and provide guidance to improve coherence with relevant legislation, including REACH24 and Eco-design.

ii. Packaging

The number of materials used for packaging is growing continuously and in 2017 packaging waste in Europe reached a record 173 kg per inhabitant, the highest level ever. To ensure that all packaging on the EU market is reusable or recyclable in an economically viable way by 2030, the Commission will reinforce the mandatory essential requirements for packaging to be allowed on the EU market and consider other measures, with a focus on:

- *Reducing (over)packaging and packaging waste*, including by setting targets and other waste prevention measures.
- *Driving design for re-use and recyclability of packaging*, including considering restrictions on the use of some packaging materials for certain applications, in particular where alternative reusable products or systems are possible, or consumer goods can be handled safely without packaging;
- *Considering reducing the complexity of packaging materials*, including the number of materials and polymers used.
- The Commission will also establish rules for the safe recycling into food contact materials of plastic materials other than PET.

iii. Plastics

The EU Strategy for Plastics in the Circular Economy has set in motion a comprehensive set of initiatives responding to a challenge of serious public concern. However, as consumption of plastics is expected to double in the coming 20 years, the Commission will take further targeted measures to address the sustainability challenges posed by this ubiquitous material and will continue to promote a concerted approach to tackle plastics pollution at global level.

To increase uptake of recycled plastics and contribute to the more sustainable use of plastics, the Commission will propose mandatory requirements for recycled content and waste reduction measures for key products such as packaging, construction materials and vehicles, also considering the activities of the *Circular Plastics Alliance*[10].

---

[10] "The Circular Plastics Alliance aims to boost the EU market for recycled plastics to 10 million tonnes by 2025. The alliance covers the full plastics value chains and includes over 300 organisations representing industry, academia and public authorities. New stakeholders can join

In addition to measures to reduce plastic litter, the Commission will address the presence of microplastics in the environment by:

- *Restricting intentionally added microplastics* and tackling pellets taking into account the opinion of the European Chemicals Agency.
- *Developing labelling, standardization*, certification, and regulatory measures on unintentional release of microplastics, including measures to increase the capture of microplastics at all relevant stages of products' lifecycle.
- *Further developing and harmonizing* methods for measuring unintentionally released micro-plastics, especially from tires and textiles, and delivering harmonized data on micro-plastics concentrations in seawater.
- *Closing the gaps* on scientific knowledge related to the risk and occurrence of microplastics in the environment, drinking water and foods.

---

the alliance by signing its declaration." Source: https://ec.europa.eu/growth/industry/strategy/industrial-alliances/circular-plastics-alliance_el

3. CIRCULAR ECONOMY IN PRODUCTION-Closing the Loop

Products can be redesigned to be used longer, repaired, upgraded, re-manufactured or eventually recycled, instead of being thrown away. Production processes can be based more on the reusability of products and raw materials, and the restorative capacity of natural resources. Turning waste into a resource is part of 'closing the loop' in circular economy systems.

During the production phase of various products or services there is an impact on the environment, supply of resources and generation of waste. The principles of circular economy are applied at the beginning of a product's lifecycle. Developing a smart product design and production processes can help save resources, avoid inefficient waste management, and create new business opportunities. The main factors contributing to close the Loop in production are:

- *"Smart" Product Design*: The main concern in "smart" design is how to be able to recover valuable materials after they have been wasted. There are initiatives by the European Commission to support product requirements under the Eco design Directive[11] that makes products more durable, and easier to repair and recycle.
- *Creating Incentives:* Create a direct economic incentive for producers to make products that can be easily recycled or reused. To support this initiative the European Commission has set an action to propose to differentiate financial contributions paid by producers in extended producer responsibility schemes based on the end-of-life costs of their products.
- *Improved production Process*: Reduce resource use and waste generation in production processes. Supporting Initiative by the European commission to promote best practices in a range of industrial sectors through Best Available Techniques Reference documents (BREFs)[12] for various industrial sectors.
- *Innovative Industrial Processes*: Clarify rules on by-products and on end-of-waste status, which will help support the development of industrial symbiosis – a process by which the waste of one

[11] "Ecodesign Directive provides consistent EU-wide rules for improving the environmental performance of products, such as household appliances, information and communication technologies or engineering. The directive sets out minimum mandatory requirements for the energy efficiency of these products. This helps prevent creation of barriers to trade, improve product quality and environmental protection." Source: https://ec.europa.eu/growth/industry/sustainability/sustainable-product-policy-ecodesign_en

[12] "The BREFs are a series of reference documents covering, as far as is practicable, the industrial activities listed in Annex 1 to the EU's IPPC Directive. They provide descriptions of a range of industrial processes and for example, their respective operating conditions and emission rates. Member States are required to take these documents into account when determining best available techniques generally or in specific cases under the Directive." Source: https://www.eea.europa.eu/themes/air/links/guidance-and-tools/eu-best-available-technology-reference

company can become the resource of another company. To promote resource efficient and innovative industrial processes, such as industrial symbiosis or remanufacturing, the European Commission supports innovative industrial initiatives under the financing programs such as Horizon 2020 and through Cohesion Policy funds[13].

[13] "The Cohesion Fund provides support to Member States with a gross national income (GNI) per capita below 90% EU-27 average to strengthen the economic, social and territorial cohesion of the EU." Source: https://ec.europa.eu/regional_policy/en/funding/cohesion-fund/

4. ZERO WASTE AND CIRCULAR ECONOMY

Zero waste and a circular economy both intend to help improve our current take-make-waste industrial and economic system, and to eliminate waste. However, there are differences between zero waste and a circular economy. Zero waste is guided by principles known as the *Zero Waste Hierarchy*, an inverted triangle that illustrates a waste management system in order of preference: Reduce through refusal or redesign, reuse and repair, recycle or compost, recover energy, and finally regulated disposal.

Circular economy model has three main principles that are more like pillars that work in together: designing out waste and pollution, keeping products and materials in use for the entire lifespan, and regenerating natural systems. Zero waste focuses on keeping waste out of the environment, while circular economy aims to regenerate the environment.

4.1 Zero waste business model

Zero waste concepts are being developed and implemented in various sectors including waste management and treatment, mining, manufacturing, and urban development. Policymakers support the zero-waste initiative because it stimulates responsible production and consumption (SDG12), optimum recycling and resource recovery.

"Zero Waste: The conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health."

Zero waste business models follow a set of guiding principles:

- Raw materials should be obtained, whenever possible, from recycled materials and not from new extraction. Any new extraction should be only justifiable when it comes from a regenerating source. A Zero waste business will be diverting 90% from landfill and incineration.
- The linear system of production needs to be changed into a circular system in which the recycling potential can be maximized.
- Production processes should be redesigned to avoid waste generation inside and outside the plant.

- Energy consumption and waste generation from the product/machine should be included in the optimization calculations.
- Applying eco-design and integrating product policy approach.
- Changing the focus from labor productivity to resources productivity.

4.2 Zero waste Hierarchy

The Zero Waste Hierarchy describes a progression of policies and strategies to support the Zero Waste system, from highest and best to lowest use of materials. It is designed to be applicable to all audiences, from policymakers to industry and the individual. It aims to provide more depth to the internationally recognized 3Rs (Reduce, Reuse, Recycle); to encourage policy, activity, and investment at the top of the hierarchy; and to provide a guide for those who wish to develop systems or products that move us closer to Zero Waste. It enhances the Zero Waste definition by providing guidance for planning and a way to evaluate proposed solutions.

When the current waste hierarchy was conceived waste management was about disposing of our waste with the minimum damage to health and the environment. Despite its non-binding nature, it has proven to be a good tool to provide guidance in the transition to modern waste management. Yet the waste hierarchy is limited and limiting because it looks at things from a solely environmental standpoint, i.e. it doesn't take into account social, economic and logistic considerations or the need to spur a transition towards circularity.

The Circular Economy model can evolve the above approach from waste management to resource management. This means that the driving force of the hierarchy should be not only the safe disposal of our waste but also to ensure that the value of our resources is preserved in the economy for the new generations.

The optimum scheme is preservation via designing waste out of the system. Designing waste out of the system by influencing consumption habits, rethinking business models, and making them waste-free by design, should be the main priority of economic and environmental EU policies and funding. This first level alone will need dedicated legislation that deals with value preservation and not with waste.

The Zero Waste hierarchy 7 levels are described below (Figure.10). Two related to products and 5 related to waste.

Figure 10-Zero waste hierarchy inverted Pyramid.

Source: https://zerowasteeurope.eu/2019/05/a-zero-waste-hierarchy-for-europe/

- Refuse, Rethink, Redesign: The 1st level encapsulates any activity related to stopping waste from being produced. Be it by creating a system that is waste free by design or by stopping the commercialization of single-use items that can be easily replaced with alternatives.
- Reduce and Reuse: Staying in the non-waste zone, the second level of the hierarchy tackles the scaling up of the market for used items which have not become waste, remain an underutilized asset of our economies or will become waste despite not having lost their use value. The goal is to prevent them from being discarded and instead find ways for them to go back in the economy.
- Preparation for Reuse: Moving into the waste area, the third level of the Zero Waste hierarchy reflects the second level of the EU waste hierarchy: preparation for reuse reproduces the efforts to clean, repair and refurbish items that have become waste in order for them to become products again.
- Recycling, Composting, Anaerobic digestion: The 4th level of the hierarchy deals with what, in an ideal scenario, should be the last option to retain materials in sustainable resource management, namely, to turn the separately collected waste into high quality secondary raw materials. This level mirrors the 3rd level of the current EU waste hierarchy.
- Material and Chemical Recovery: As explained, the Zero Waste hierarchy differs from and supplements the EU's one in the configuration of its lowest levels. The EU waste hierarchy places energy recovery as the next step after recycling, whilst the Zero Waste hierarchy prioritizes the

extraction of valuable materials from the mixed waste and the discards from sorting processes. This is better aligned with the vision of Circular Economy, which is basically about retaining materials and resources within the loop, whereas thermal treatment shows as a “leakage of resources”. Material Recovery and Biological Treatment operations on mixed waste in systems with high separate collection rates –as it is demanded by the new EU waste legislation- provide a cost-effective way to preserve the value of resources whilst minimizing disposal. The new technologies related to chemical recycling also fit in this level if they deal with the discards of sorting processes -and not with separately collected streams- and they transform used polymers into new ones.

- Residuals Management: The current EU waste legislation obliges to source separate and separately collects the waste streams, allowing for most of the biologically active waste to be diverted from the residual waste. By means of prior biological stabilization, the waste can be safely landfilled, in full compliance with the Landfill Directive and related obligation on pre-treatment. Such systems may be designed to work on increasing amounts of source separated organics and decreasing amounts of residual waste. The transition that Europe is going to see in the coming years, very much depending on the success in advancing towards waste-free systems by design –see levels 1 and 2-, should see the amounts of residual waste dwindle and will require flexibility to adapt to the new scenario.
- Unacceptable: The new hierarchy qualify as unacceptable the options creating lock-in effects that obstruct the transition, destroy resources and/or are environmentally unacceptable. Landfilling of non-stabilized waste, littering and any sort of combustion or co-combustion of mixed waste, with or without oxygen, are options that should become part of the past because they contradict the EU decarbonization agenda and absorb investments that should be directed to the highest levels of the hierarchy.

5. PLASTICS PRODUCTION (Single-Use) AND CIRCULAR ECONOMY

Plastic is the most used material in our economy and daily lives, having multiple functions and applications in society. It is a lightweight, hygienic, and resistant material which can be molded in a variety of ways and utilized in a wide range of applications. There are two main categories of plastics (Figure.11).

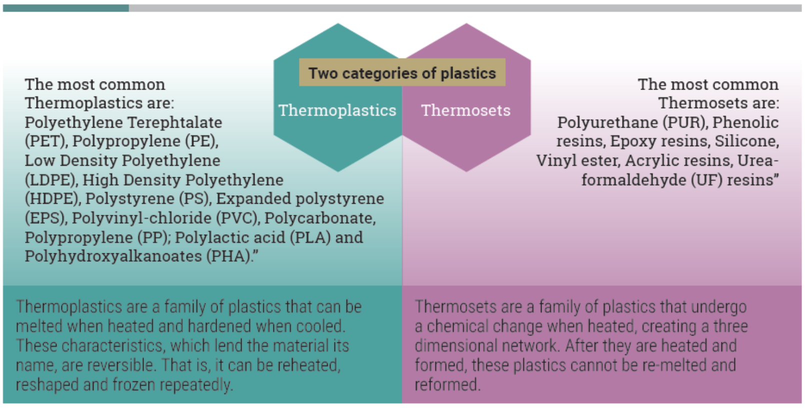


Figure 11-The two main categories of plastics and their single-use applications.
Source: UNEP, Plastics: A Roadmap for Sustainability. *2018.*

Unlike metals, plastics do not rust or corrode. Most plastics do not biodegrade, but instead photodegrade, meaning that they slowly break down into small fragments known as microplastics. The fragmentation of large plastic items into microplastics[14] is common on land such as beaches because of high UV irradiation and abrasion by waves, while the degradation process is much slower in the ocean due to cooler temperatures and reduced UV exposure. Single-use plastics, often also referred to as disposable plastics, are commonly used for plastic packaging and include items intended to be used only once before they are thrown away or recycled. These include, among other items, grocery bags, food packaging, bottles, straws, containers, cups, and cutlery. (Figure.12) introduces the main polymers used to manufacture single-use plastic items and indicates their most common applications.

[14] Primary microplastics are those originally produced at the micro-size level for applications such as cosmetics or industrial scrubbers; secondary microplastics are fragments at the micro-size level that have resulted from the breakdown of larger plastic products. Source: GESAMP, 2015b.

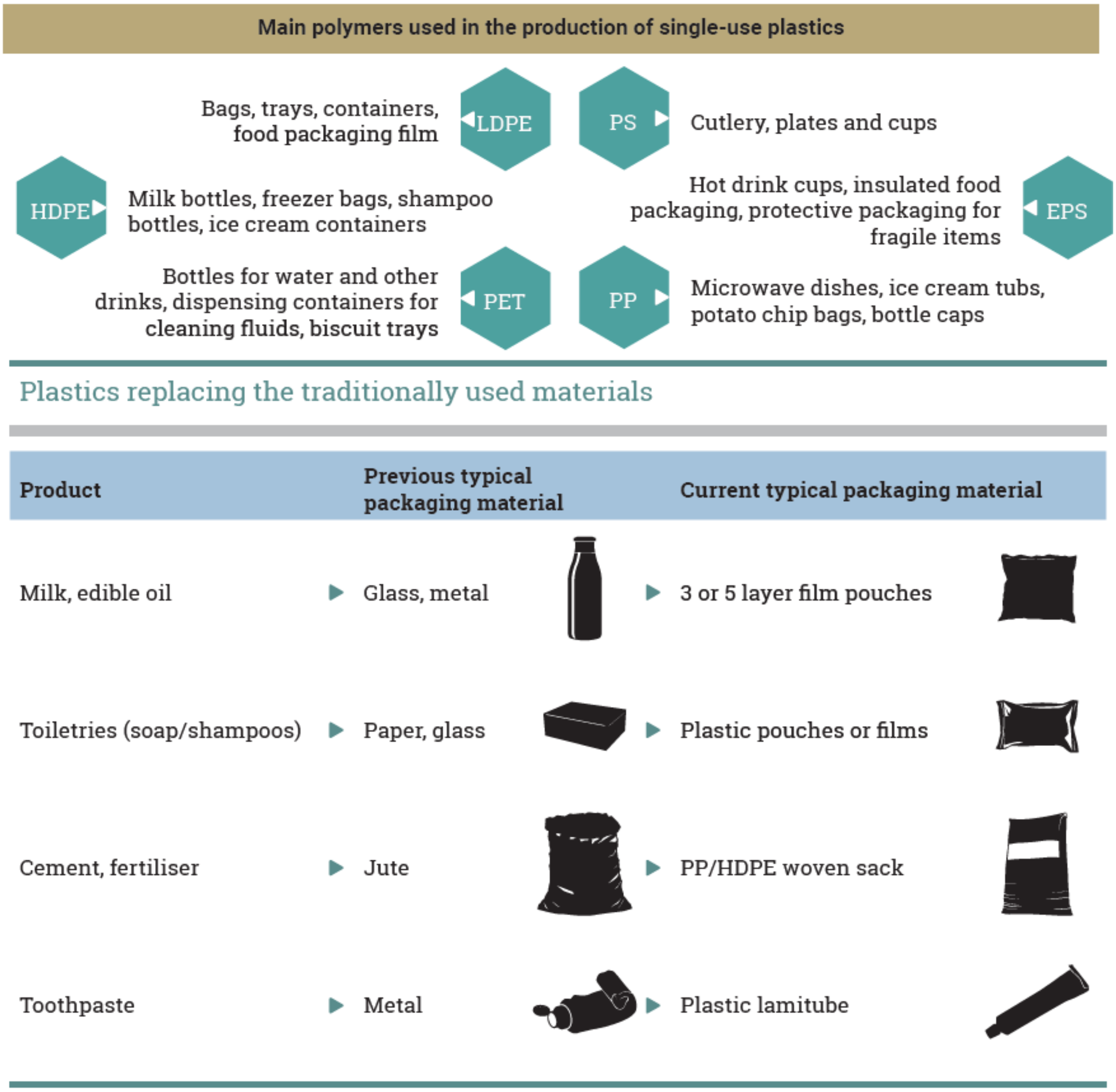


Figure 12-Plastics replacing the traditionally used materials.

Source: UNEP, Plastics: A Roadmap for Sustainability*. 2018.*

The growth in the production of plastic has largely increased and is now overcomes that of any other material, with a global shift from the production of durable plastics to single-use plastics (including packaging), as shown in (Figure.13). The production of plastic is largely reliant on fossil hydrocarbons, which are non-renewable resources. If the growth in plastic production continues at the current rate, by 2050 the plastic industry may account for 20% of the world's total oil consumption. More than one-fourth of the resins globally used in the production of single-use plastics are manufactured in Northeast Asia. This is followed by North America, the Middle East and Europe (Figure.14).

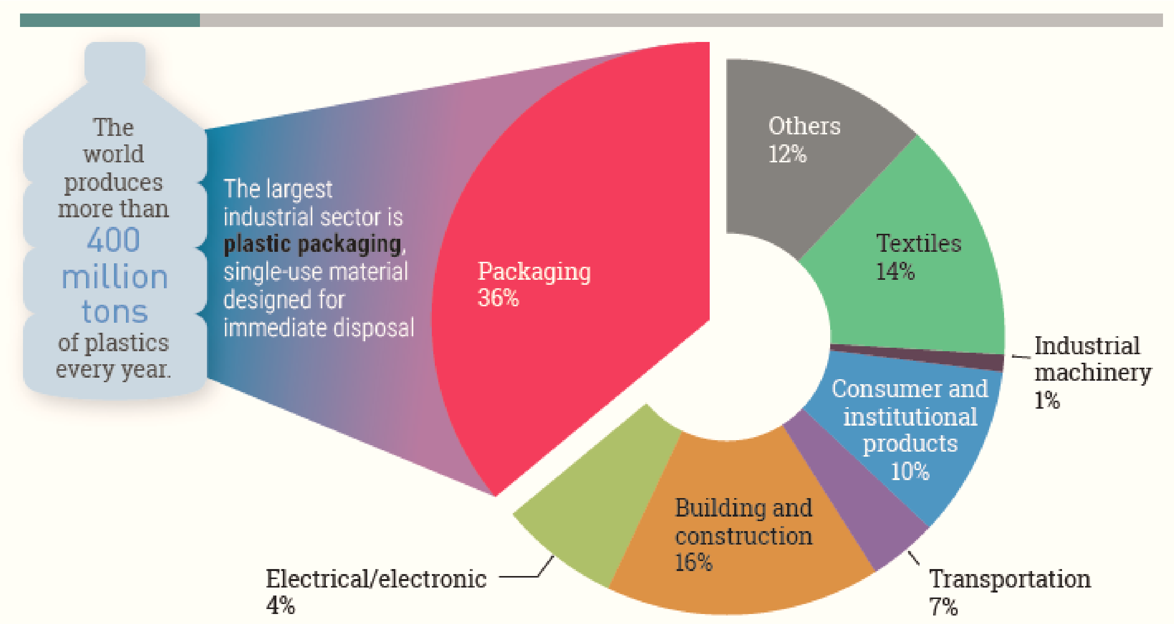


Figure 13-Global plastic production by industrial sector, 2015.

Source: UNEP, Plastics: A Roadmap for Sustainability. *2018.*

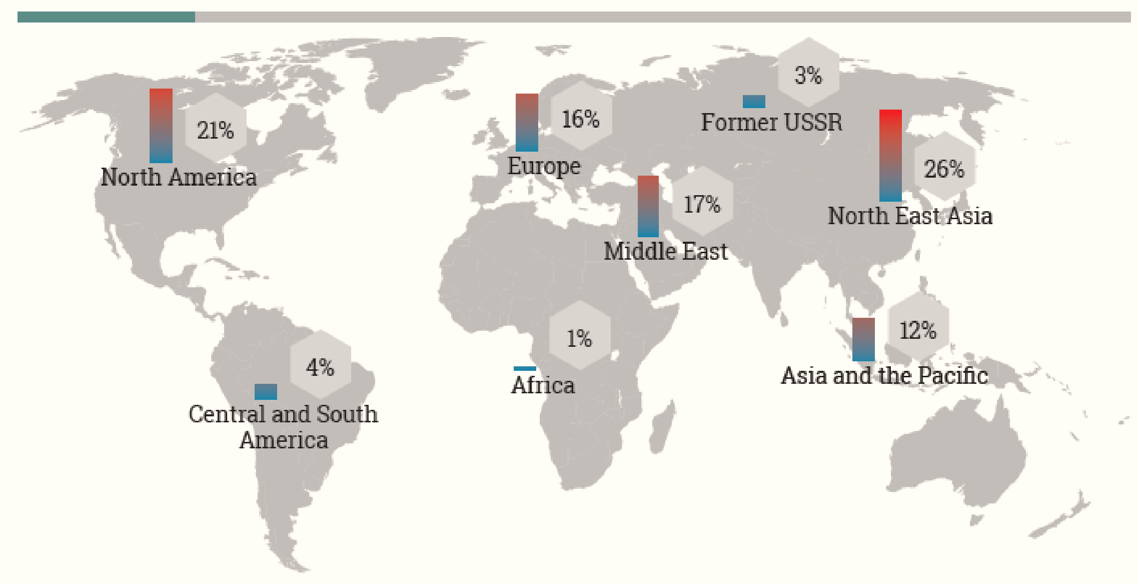


Figure 14-Distribution of single-use plastic[15] production by region (2014).

Source: UNEP, Plastics: A Roadmap for Sustainability. *2018.*

The way plastics are currently produced, used, and discarded fails to capture the economic benefits of a more 'circular' approach and harms the environment. There is an urgent need to tackle the

---

[15] The graph reflects data on the production of virgin and recycled LDPE, HDPE, PS and EPS. PET and PP are excluded from the analysis due to lack of region-specific data. (Source: UNEP, *Plastics: A Roadmap for Sustainability*. 2018.)

environmental problems caused by the production, use and consumption of plastics (Figure.15). Rethinking and improving the functioning of such a complex value chain requires efforts and greater cooperation by all its key players, from plastics producers to recyclers, retailers, and consumers. It also calls for innovation and a shared vision to drive investment in the right direction.

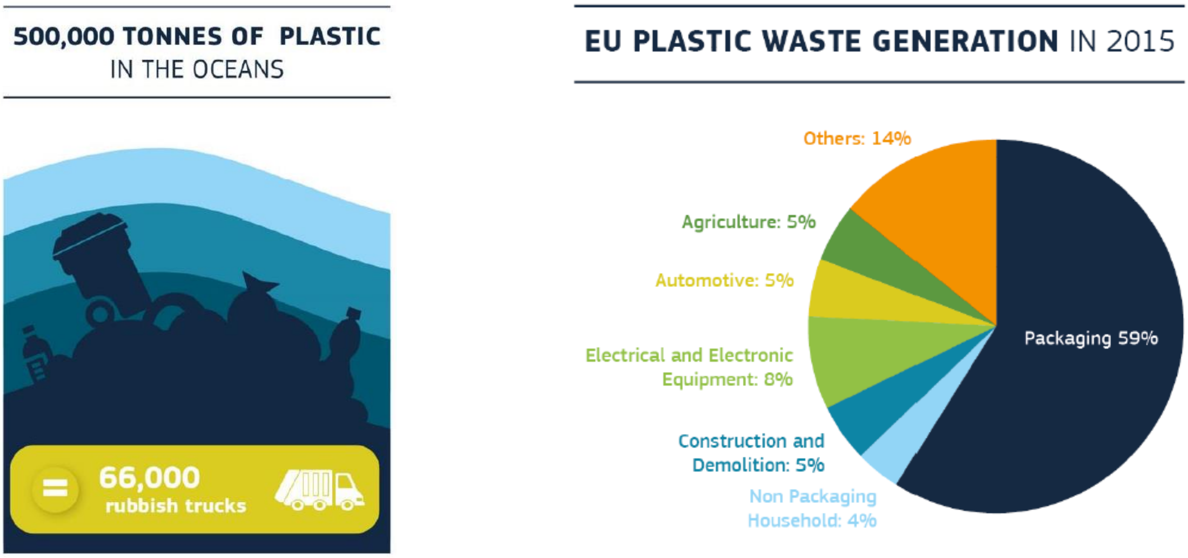


Figure 15- Plastics waste infographics.

Source: European Union, 'Report for European Commission DG Environment. Study to support the development of measures to combat a range of marine litter sources Incentivising Waste Disposal at Ports', no. January, 2016, [Online]. Available: http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/MSFD Measures to Combat Marine Litter.pdf.

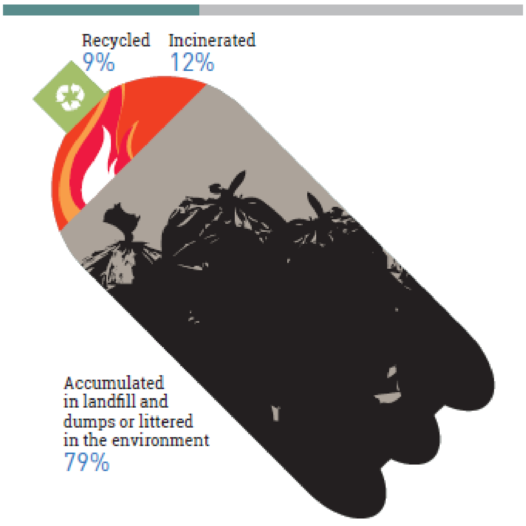
5.1 Plastics Waste management

The non-biodegradable nature of petroleum-based plastics has hazardous effects to the environment due to their abundance in the waste stream. Their abundant presence in the waste stream poses critical challenges especially without effective waste management. Many countries accumulate waste plastic pyramids requiring proper disposal; however, due to the cost of waste disposal, many rely on indiscriminate plastics dumping. Plastics are composed of a wide range of complex chemical compounds formed into varying products, and various plastic resins are not easily differentiated. The main challenge in plastic handling is on collection, separation, and recycling of Plastic solid waste (PSW). The durability of plastics causes their accumulation and persistency in the environment with estimated rate of over 25 MT per year.

At the end of its lifetime, a product or packaging is recycled, incinerated, landfilled, dumped in uncontrolled sites, or littered in the environment (Figure.16)

Figure 16- Jourvey of products at end of life.
Source: https://doi.org/10.1126/sciadv.1700782

According to recent estimates,18 79% of the plastic waste ever produced now sits in landfills, dumps or in the environment, while about 12% has been incinerated and only 9% has been recycled. If current consumption patterns and waste management practices do not improve, by 2050 there will be about 12 billion tons of plastic litter in landfills and the natural environment (Figure.17). Energy recovery processes are preferable to landfilling or improper forms of disposal. However, if the desire to recoup the large investment required to set up energy recovery infrastructures indirectly discourages policies geared at reducing plastic waste generation, this would be problematic. In the waste management hierarchy, prevention of waste should always take priority (Figure.18).



Largest generators of mismanaged plastic waste (2010)		
China	8.8 million Mt/year	27% of world total
Indonesia	3.2 million Mt/year	10% of world total

Figure 17- Disposal of all plastic waste ever generated (as of 2015).

Source: https://doi.org/10.1126/sciadv.1700782

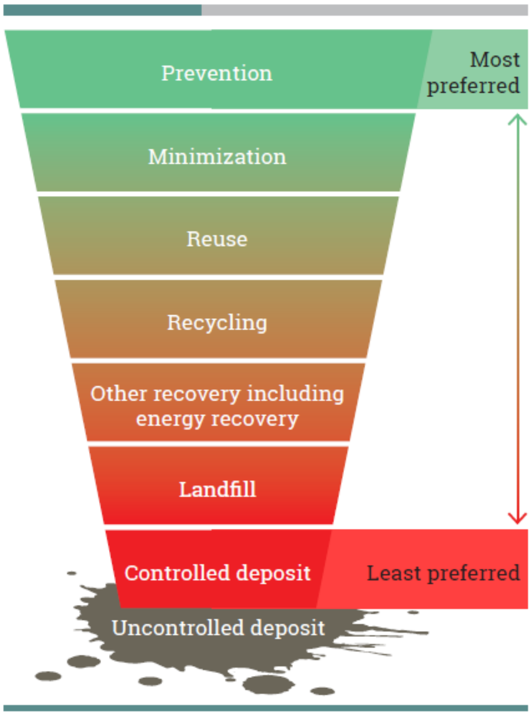


Figure 18 - Waste management hierarchy

Source: https://www.science.org/doi/10.1126/science.1260352

5.2 The New Plastics (Circular) Economy

The vision of New Plastics Economy is that plastics never become waste and they re-enter the economy as valuable technical or biological nutrients. The New Plastics Economy is underpinned by and aligns with circular economy principles. It sets the ambition to deliver better system-wide economic and environmental outcomes by creating an effective after-use plastics economy (the cornerstone and priority); by drastically reducing the leakage of plastics into natural systems and by decoupling plastics from fossil feedstock (Figure.19).

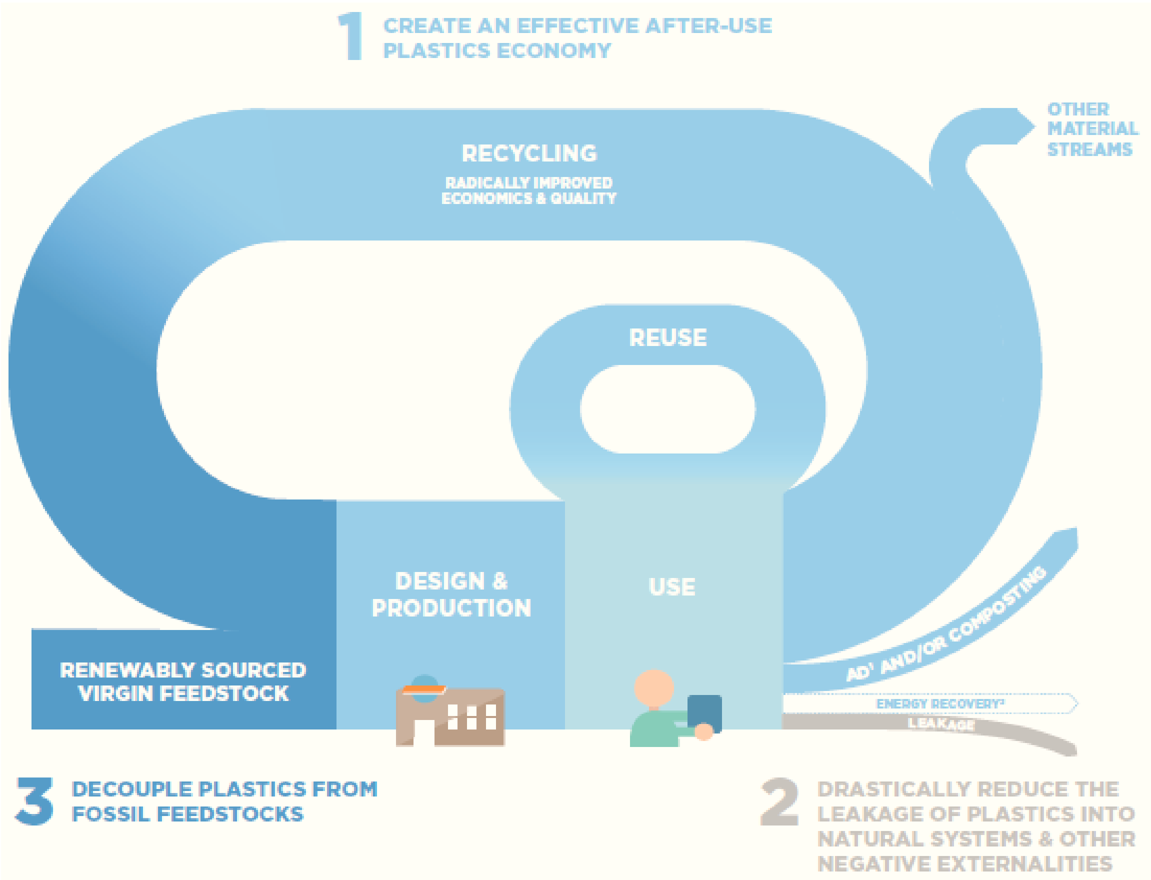


Figure 19- Ambitions of the New Plastics Economy.

Source: Ellen MacArthur Foundation, 'The New Plastics Economy: Rethinking the future of plastics', Ellen MacArthur Foundation, *no. January, p. 120, 2016.*

A smart, innovative, and sustainable plastics industry, where design and production fully respect the needs of reuse, repair, and recycling, brings growth and helps reduce greenhouse gas emissions and dependence on imported fossil fuels.

Creating an effective after-use plastics economy is the cornerstone of the New Plastics Economy and its priority. Not only is it critical to capture more material value and increase resource productivity, but it also provides a direct economic incentive to avoid leakage into natural systems and helps enable the transition to renewably sourced feedstock by reducing its scale.

Plastics should not end up in the ocean or other parts of the environment. Ensuring this doesn't happen requires a coordinated effort to improve collection systems and recovery infrastructure especially where the latter lags economic development, as is the case for many rapidly developing middle-income countries in Asia, which account for an estimated 80% of leakage. Various local and global initiatives address the critical development of infrastructure and work with the formal and informal waste management sector to stop plastics from leaking into the ocean. Local initiatives include, for example, the Mother Earth Foundation[16] and Coastal Cleanup in the Philippines, while the Trash Free Seas Alliance[17], initiated by the Ocean Conservancy, is an example of an effort aimed at effecting change on a global scale.

It is essential to bring together the different actors in a cross-value chain dialogue mechanism and drive change by focusing on efforts with compounding effects that together would have the potential to shift the global market. Analysis to date suggests that the initial areas of focus could be:

1. Establish the Global Plastics Protocol and coordinate large-scale pilots and demonstration projects.
2. Mobilize large-scale, targeted "moon shot" innovations.
3. Develop insights and build a base of economic and scientific evidence.
4. Engage policy-makers.
5. Coordinate and drive communication.

[16] http://www.motherearthphil.org/
[17] https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/

6. CIRCULAR ECONOMY STRATEGIES FOR SINGLE USE PLASTICS

While waste elimination through selection of materials, product design and business models should be prioritized, the tasks accomplished by plastics will lead to discarded materials at some point. All those materials need to be recycled in an effective system. Materials should be re-entered in the plastics value chain. The level of global interest in plastic production, consumption and waste has soared in recent years. While much of this focus has been on the risks and impacts, it is important to recognize that the flexibility and resilience of plastic means that products made from the material perform many crucial functions in society and across sectors. The plastic value chain is complex, touching most (if not all) businesses sectors globally (Figure.20).

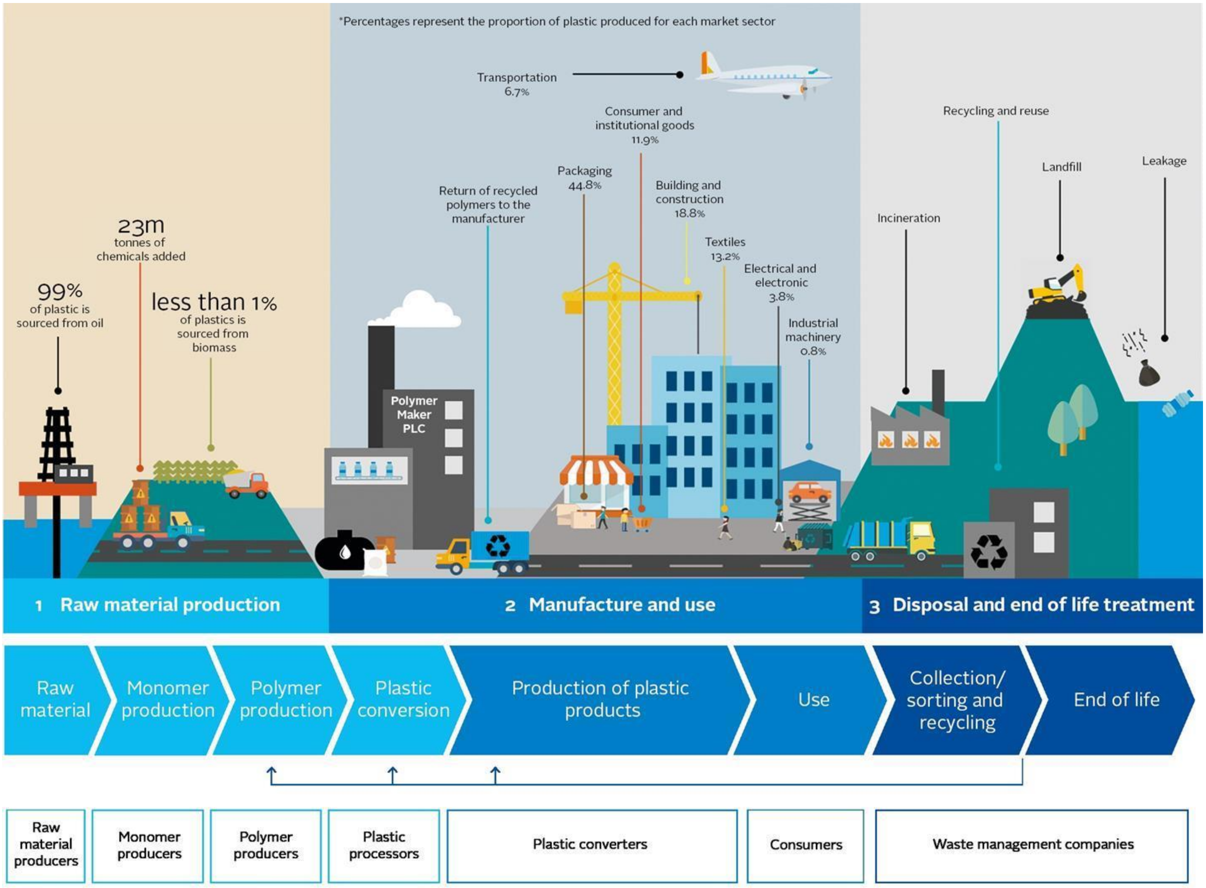


Figure 20- Overview of the global plastic supply chain.

Source: https://www.unpri.org/plastics/risks-and-opportunities-along-the-plastics-value-chain/4774.article

Investor portfolios across the value chain are exposed to an array of risks and opportunities associated with plastic. These risks are listed below and associated according to the various value chain stages as seen in Figure.21.

- Reputational: Increased public and civil society scrutiny demanding a shift away from plastic production and use.
- Regulatory: Bans, taxes, levies or regulation of plastic production, use and disposal
- Impact of using alternative materials: Increased availability of plastic alternatives at equivalent or lower costs
- Access to feedstock: Accessing raw materials in the supply chain to produce recycled plastics
- Access to recycled content: Accessing recycled plastics to meet voluntary commitments and company pledges or new regulations
- Emerging market risks: Scalability of new business models and market acceptance of new products and technologies

STAGE OF VALUE CHAIN	SECTOR	REPUTATIONAL	REGULATORY	USE OF ALTERNATIVES	ACCESSING FEEDSTOCK	ACCESSING RECYCLED CONTENT PLASTIC	EMERGING MARKET
Raw materials production	Oil and gas	Short term	Low	Long term	Low	N/A	N/A
	Agricultural products (corn and sugarcane)	Short term	Low	N/A	Medium term	N/A	N/A
Primary plastics production	Chemicals (oil-based)	Medium term	Long term	Long term	Low	N/A	Low
	Chemicals (bio-based)	Short-medium term	Medium term	N/A	Medium term	N/A	Short term
Secondary plastics production	Waste management (recycled content plastic)	Low	Medium term	Medium term	Short term	N/A	Medium term
Manufacture and use	Containers and packaging	Short term	Short term	Short term	N/A	Short term	Low
	Engineering and construction services and home builders	Low	Low	Low	N/A	Short term	Low
	Consumer goods	Short term (for specific products) Low for other products	Short term (for specific products) Low for other products	Short term (for specific products) Low for other products	N/A	Short term	Low
	Industrial machinery and goods	Low	Low	Low	N/A	Short term	Low
	Transportation	Low	Low	Low	N/A	Short term	Low
	Apparel and textiles	Medium term	Low	Medium term	N/A	Short term	Low
Disposal	Collection/export	Short term	Medium term	Medium term	N/A	N/A	Low
	Plastic recycling	Low	Low	Medium term	Short term	N/A	Short term (for specific products) Low for other products

Figure 21- Plastic-related risk assessment across the value chain.

Source: G. James, 'An investor initiative in partnership with UNEP Finance Initiative and UN Global Compact THE PLASTICS LANDSCAPE: RISKS AND OPPORTUNITIES ALONG THE VALUE CHAIN', pp. 6–14, 2017, [Online]. Available: https://www.unpri.org/download?ac=10258.

Each stage of the value chain is assessed in the following sections with opportunities or solutions also identified. However, possible solutions should consider:

- The real-world context – this includes existing systems or processes that may affect operations
- Potential unintended consequences – fundamental ESG principles (e.g. traceability of supply chain) should be applied to the project or company assessment
- Scalability – this will depend on the market and context of operation Collaboration across the value chain is required to develop impactful solutions.

Emerging strategies can be used to implement circular economy principles and close the Loop within the plastic lifecycle. As a technical cycle, this implies that plastic packaging is reused when possible (circulating the packaging product), then recycled (circulating the packaging materials) see Figure.22.

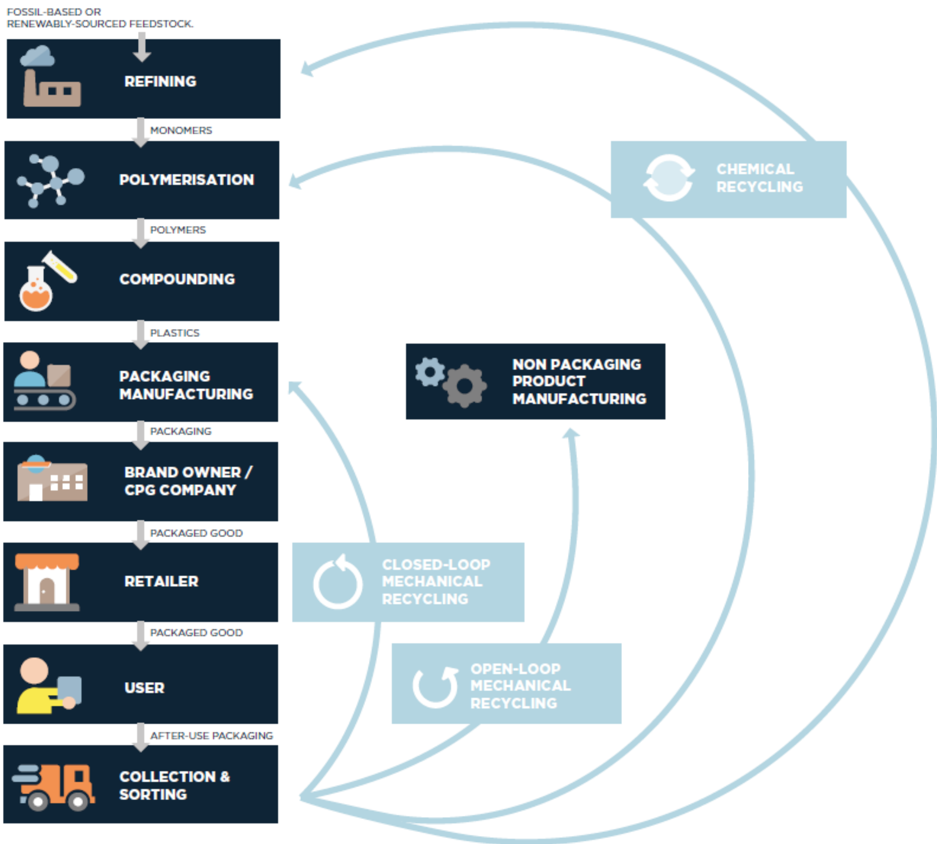


Figure 22- Overview of Recycling types.

Source:G. James, 'An investor initiative in partnership with UNEP Finance Initiative and UN Global Compact THE PLASTICS LANDSCAPE: RISKS AND OPPORTUNITIES ALONG THE VALUE CHAIN', pp. 6–14, 2017, [Online]. Available: https://www.unpri.org/download?ac=10258.

Within recycling, this principle results in a general order of preference:

1. Mechanical recycling in closed loops.

This is the most value-preserving loop. Mechanical recycling keeps polymers intact and hence preserves more value than chemical recycling, where polymers are broken down. Closed-loop mechanical recycling keeps the quality of the materials at a similar level by cycling materials into the same application (e.g. from PET bottle to PET bottle) or into applications requiring materials of similar quality. As such, mechanical closed-loop recycling not only preserves the value of the material, it also maintains the range of possible applications in future, additional loops.

2. Mechanical recycling in open loops ('cascading').

Given the inherent quality loss during mechanical recycling, closed-loop mechanical recycling cannot continue indefinitely. Open-loop recycling plays an important role as well. In open-loop mechanical recycling, polymers are also kept intact, but the degraded quality and/or material properties require applications with lower demands. Cascading to the highest-value applications each cycle could help maximize value preservation and the number of possible loops.

3. Chemical recycling.

Chemical recycling breaks down polymers into individual monomers or other hydrocarbon products that can then serve as building blocks or feedstock to produce polymers again. As such, it is less value preserving than mechanical recycling. Chemical recycling technologies are not yet widespread and/or not yet economically viable for most common packaging plastics. However, as they could enable after-use plastics to be upcycled into virgin-quality polymers again, they could become an option for materials for which mechanical recycling is not possible (e.g. most multi-material packaging or plastics that cannot be cascaded any further).

The rank order above offers a general order of preference and target state to innovate towards, but, should not be seen as a strict hierarchy for determining the best option for every single piece of packaging today.

6.1 COLLECTION AND SHORTING

The main plastics demand nowadays is made up of 80 % thermoplastics such as PP, PE and PET, 15 % thermosets that cannot be remolded or reheated, such as polyurethane (PU), epoxy resins, and phenolics, and 5 % of other, specialized materials. After-use collection, sorting and recycling systems of most, if not all, of these materials are underperforming, mainly because of the increased material diversity and complexity, especially in comparison to other more homogeneous materials such as metals or glass (Esbensen & Velis, 2016 and Deloitte Sustainability, 2017). The rate of collection for recycling varies considerably across Europe, even within the same polymer type.

The capacity for collection, sorting and recycling may differ across regions and is insufficient to transition towards a circular economy for plastics. While collection and sorting are essential requirements to retain the value of products and materials, the existing infrastructure is insufficient in several places, or it needs to be modernized to enable high-quality recycling (European Commission, 2018j). As reflected in recent policymaking, separate collection of different material streams and investment in further sorting and recycling capacity are considered important, while avoiding infrastructural overcapacity for processing mixed waste, e.g. incineration (European Commission, 2018h and European Commission, 2018j).

Collection and sorting performance depends on a complex and continuously evolving plastics landscape. There are thousands of different plastics and additives, and there is increasing consensus that this complexity, especially in packaging, prevents effective source separation. In addition, the materials landscape is evolving constantly due to both established and emerging socioeconomic and material- level innovation trends, including:

- *Light-weighting.* Replacement of materials (e.g. metal, glass) with composites that are lighter, cheaper and can be formed into more complex shapes, are more convenient and shatter – resistant.
- *New materials and manufacturing techniques*. Lighter or new materials are often a result of new production technologies. There are continuous efforts in the direction of new materials. Innovation trends affecting packaging include nanotechnology, active and intelligent packaging (e.g. indicating food freshness) and bio-based and/or biodegradable plastics. Other factors are decentralization, localization and down-scaling of manufacturing trends such as 3D-printing, and the emergence of wearables creating a new category of complex products.
- *New business models and societal trends*. Changing food production, evolving cooking and eating lifestyles, international shipments and e-commerce, augmented reality and quick response codes; all these things introduce new needs for packaging. In addition, the aging European population, migration, urbanization and adoption of global consumer values about what constitutes prosperity and well-being, all impact the type of plastics produced, used and disposed of.
- *Global trade*. Increased manufacturing outside Europe and imports, and international fast-moving consumer goods (FMCG) introduce increased challenges and questions on how to control waste material flows (Farmer, 2013).

These developments may affect plastic waste composition in a combination of ways. In the case of packaging, i.e. the largest plastics application in Europe and globally, the consumer goods and retail sectors play a critical role in the selection of materials. Due to the high and still increasing complexity of packaging and other plastic products, it is difficult to sort the different materials in a cost-effective way. The complexity of products and material combinations are such that difficulties occur even within the same sector of activity and for similar applications, formulation of the plastic material might vary. Even relatively widely collected items bring challenges. For example, clear PET bottles end up in the same material stream as clear PET trays, where the latter are more diverse through differences due to additives and the formation process. As a result, during the grinding steps of the recycling processes, bottles will be shredded into homogenous scraps while trays will tend to produce smaller scraps, more heterogeneous parts, and more dust which might not be efficiently recycled (FP7 GREEN PACK). Product design lacks efficiency, and products are often not designed for optimal collection and sorting. Collection and sorting systems have difficulties in keeping up with the rapid emergence of new materials across different sectors and regions. There is a lack of knowledge about variations in the collection system. Current recycling innovation efforts are attempting to build new databases for the material collected, however cloud based data management is expensive. Taking into consideration the above challenges in the efficient shorting and collection of plastics volumes across different regions the bellow recommendations can be addressed regarding policy measures and Research and innovation leverage

Policy framework recommendations

Ensure full implementation and enforcement of the EU waste legislation. This should guarantee proper collection and sorting of used materials across the EU. Member States should be encouraged to develop laws against improper disposal by industry and citizens alike, and to develop corresponding penalties.

Develop a mechanism for gathering and sharing information on collection and sorting performance. Guided by best practice, such a system should lead to simplification, standardization, and reduction of variability at all levels of plastics lifecycle. Design, manufacturing, retail, use, pre-sorting, collection, sorting and (organic) recycling (Dri, Canfora, Antonopoulos & Gaudillat, 2018; Esbensen & Velis, 2016 and Velis, Lerpiniere & Coronado, 2015). The incentives for simplification should be aligned across stages and sectors. The main challenge lies upon economies of scale with heterogeneous streams, and assessment is necessary for feasibility and affordability (Figure.23). Given the considerable challenges in designing for collection, sorting and recycling, the insights generated should be shared with collection and sorting sectors as well so as to create an effective stream of data exchange to optimize the shorting and collection process. Harmonize collection systems across the EU, allowing a certain degree of local adaptation to socioeconomic conditions, aiming in the simplification of the citizen's participation. This harmonization will allow packaging producers and brand owners to follow a common design guideline fit for collection and sorting across Europe. A suitable regulatory framework could encourage and facilitate convergence of best practices, allowing for a reasonable level of local differentiation.

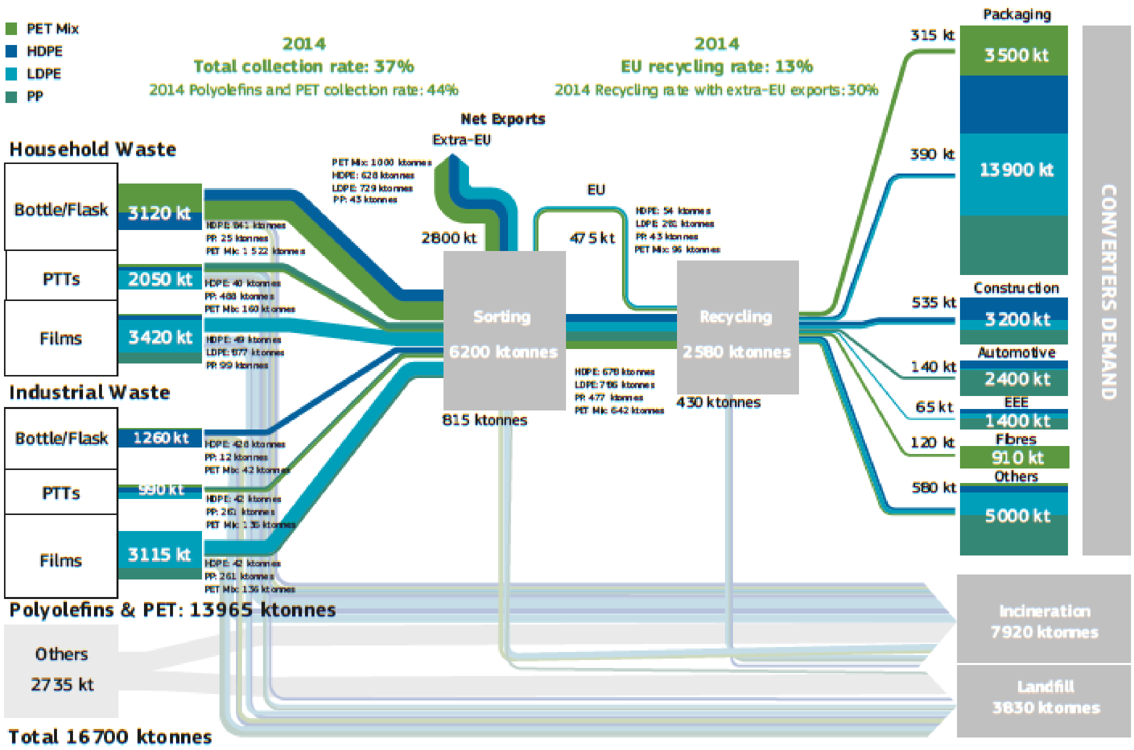


Figure 23-Overview of European plastic streams.

Source: European Commission, A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions*. 2019.*

R&I framework initiatives

Create funding initiatives for research on value capture optimization of separate collection of plastics and/or other materials. Have a better understanding of the compatibility of waste stream in order to decide upon streams that can be co-collected and co-processed.

Provide financial incentives for innovation in methodologies to accurately quantify and forecast the generation rate and source of emerging waste composition. The emerging digital technologies and societal trends offer a major opportunity to incorporate into the wave of innovation the requirements for embedding and costing in solutions for collection and sorting. In addition, this would provide ways to address the increased variability and contamination, which are key aspects of value drop at the end of the first-use cycle (Esbensen & Velis, 2016).

Provide funding for research into interdisciplinary solutions to manage and reduce plastics complexity at the application level, if beneficial from the economic, environmental and social perspective. A business-as-usual scenario would most likely just result in more complex and cross-contaminated material flows, increasing the current challenges (Velis, Lerpiniere & Coronado, 2015). To ensure emerging or changing sectors embed circularity in their activities and simplify the landscape right from the start, disruption of the current materials, products and business model innovation model is needed. Such disruption can be encouraged by incorporating socioeconomic and behavioral aspects into interdisciplinary efforts. The challenges of such research include establishing common terminology and applying compatible methodologies across disciplines. Lessons from collection and sorting systems prevalent in developing economies, such as detailed manual sorting of plastics performed by waste pickers, would provide insights for both manual pre-sorting and robotic sorting (Purshouse et al., 2017).

6.2 MECHANICAL RECYCLING

Mechanical recycling can offer economic and environmental benefits. One of the main principles of the circular economy is to preserve value in material cycles by maintaining the materials' structural integrity. One of the most value-preserving cycles (or 'loops') are repairing/maintenance as well as reuse, for which there is significant potential especially in durable plastic products. However, for a large share of plastic packaging, recycling is crucial to create circular material flows, and the principal 'innermost' of different recycling loops is mechanical recycling.

Mechanical recycling is a robust and comparatively efficient way of reprocessing plastics into new resin that can be put back into the value chain. For plastic waste, mechanical recycling is the preferred recycling solution if ecologically most beneficial, technologically possible, and economically attractive. Chemical recycling will complement mechanical recycling. At present the most prevalent end uses regarding plastics usage are in the following the sectors:

- Packaging: in bottle-to-bottle applications for clear and transparent PET, but also through the production of sheets used in thermoforming processes.
- Construction: mainly for pipe production, insulation and carpets.

- Automotive: mainly for bumpers and for hidden parts.
- EEE: used for dark-coloured products, and irons, printers, fans, etc.
- Fibres: this market is one of the major applications of recyclate, especially for non-woven interlining fabric (e.g. chemical suits, protection overalls, etc.) and automotive interiors.
- Others: this category concerns smaller markets, such as furniture and consumer goods (e.g. clothes, hangers and boxes) and strapping.

Mechanical recycling efficiency depends on material complexity. With the rapid increase in complex materials, in packaging and elsewhere, mechanical recycling can be expected to struggle due to two main reasons: firstly, the lack of adequate capacity to process complex materials into their purified components for subsequent use; secondly, issues with mixing when complex materials are not fully separated from mono-materials during collection and sorting. Recycling of complex materials (e.g. composites, multilayer packaging, and associated adhesives) can be improved, and various methods are under development.

Lack of quality, competitive pricing and regulations make it difficult for mechanically recycled plastics to compete with virgin plastics. The current mix and contamination level of collected and sorted after-use plastics going to mechanical recycling, in combination with the available processing technologies, mean that the compounds produced from recycled resin are mainly used for lower quality products (e.g. bin bags, recycled bins and plastic furniture).

With high uncertainty about input material composition and future demand, designing a mechanical recycling system fit for purpose is difficult. It is impossible to determine an effective mechanical recycling system without taking into account how the plastics system as a whole will function. Aspects affecting the recycling operations and business case cover the entire value chain, including business models (e.g. deposit-refund schemes for specific containers), product design (e.g. design for disassembly), societal and marketing trends (e.g. growth of multilayer packaging), material choices (e.g. recycling capacity for PLA or PEF), and the role of chemical recycling (e.g. mechanical recycling co-location with chemical recycling). While the shortcomings of the recycling system today are well-known, e.g. its inability to produce high-quality recycled materials; solutions to address them rely heavily on external factors upstream in the plastics value chain.

Policy framework recommendations

Make regulatory requirements in order to increase demand for recycled input material especially in high-quality applications in order to drive investment and innovation towards improved recycling yields and quality. These measures could be supporting a well-functioning secondary materials market, and targets for recycled content and quality of recycled material. Safety aspects must be taken into account (e.g. hazardous legacy elements) and implementation (e.g. method to verify recycled content).

Recognizing that low-quality recycling is not enough to move towards a circular economy for plastics, as significant material value is lost, it is important to ensure high-quality recycled materials. Set up fiscal framework to support the uptake of recycled polymers. Rebalancing true cost of virgin plastics, including environmental and social impact, can improve competitiveness of recycled plastics (see e.g. CVORR[18]). Measures could include VAT reduction for use of recycled plastics, or different EPR fees for virgin versus recycled content. These fiscal measures can be mutually reinforcing with regulatory ones, such as targets on minimum recycled content. Set up a cross-value chain platform. Value chain innovation is defined as the transformation of "traditional" value chains into new ones through cross-border and cross-sectorial collaboration. In these platforms the role of mechanical recycling in a future circular plastics system can be discussed. This platform should:

- Consider emerging technologies such as: Traceability systems and de-polymerization.
- Identify key system design and investment needs at EU and national level.
- Provide business guidance on value-preserving cascading or final-sink treatment of legacy composite materials.

The guidelines should help decide how to design the most economically productive pathways and handle legacy substances.

R&I framework initiatives

Provide financial incentives for innovation in more efficient and economic solutions for mechanical recycling of polymer materials. Improved recycling processes are one key component of achieving higher-quality recycled materials at competitive pricing. Incentives could include grants, equity funding and public procurement.

6.3 CHEMICAL RECYCLING

While mechanical recycling is in general the preferred option, there will always be after-use plastics that cannot or can no longer be mechanically recycled into a valuable product, such as multi-material

[18] https://cvorr.leeds.ac.uk/

packaging or materials that have completed their maximum number of cascading cycles. This is where chemical recycling could play a role in closing the loop back to chemical feedstock again, enabling 'infinite' loops. Chemical recycling is not yet applied at large scale.

Reprocessing technology using chemical agents or processes that directly affect either the formulation of the plastic or the polymer itself. This contrasts with mechanical reprocessing, which only uses physical methods to separate different types of plastics. While other categorizations exist, in this report three main types of chemical recycling are distinguished, which differ significantly in how they work and what outputs they produce (Figure. 24).

- Solvent-based purification is a process in which the plastic is dissolved in a suitable solvent, in which a series of purification steps are undertaken to separate the polymer from additives and contaminants. The resulting output is the precipitated polymer, which remains unaffected by the process and can be reformulated into plastics.
- Depolymerization is the reverse of polymerization and yields either single monomer molecules or shorter fragments often called oligomers.
- Feedstock recycling is any thermal process that converts polymers into simpler molecules. The two main processes here are pyrolysis and gasification.

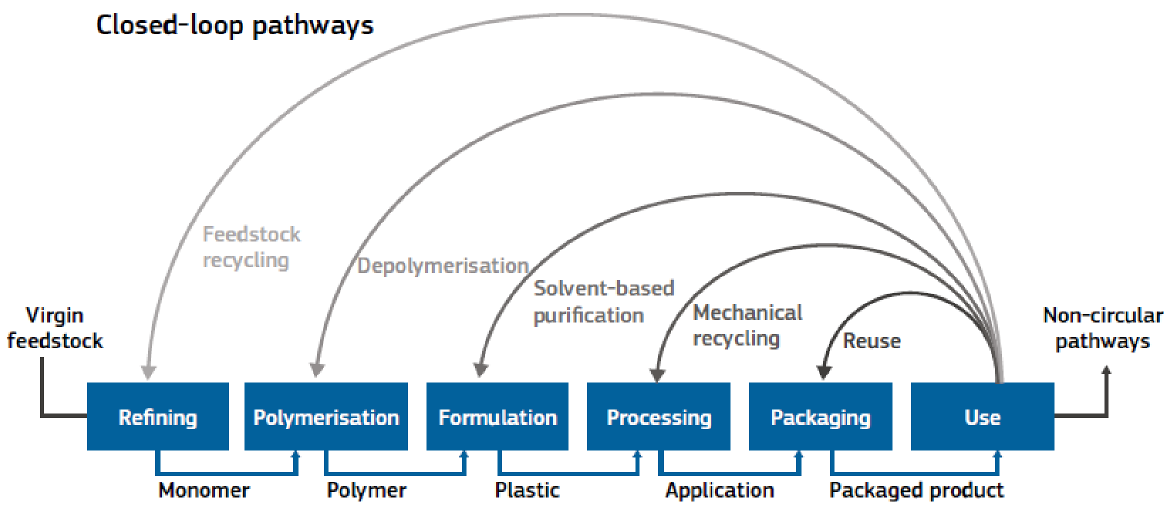


Figure 24- Overview of different loops for plastics in a circular economy.

Source: European Commission, A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions. *2019.*

Chemical recycling technologies have the potential to bring clear benefits which complement mechanical recycling. However, they should not be perceived as silver-bullet solutions to deal with mixed and contaminated plastics streams. As explained in this report, to achieve the much-needed systemic change, downstream innovation should go hand in hand with upstream solutions that redesign and innovate business models, products, and materials. Chemical recycling technologies still need significant development to mature. Environmental and social impacts of chemical recycling need to be evaluated at the industrial level.

There is no EU-wide vision of a holistic recycling system that incorporates chemical alongside mechanical recycling. There is no obvious answer as to how much capacity is needed for the different forms of chemical recycling, and how they influence the required capacity for sorting and mechanical recycling. While one could argue that market forces should decide, such an approach could have unintended consequences. If different chemical recycling technologies were all to be implemented at scale alongside existing recycling infrastructure, the system would significantly increase its after use pathways, as well as the multiple combinations of material flows between them.

Policy framework recommendations

Develop a vision for a holistic recycling system in Europe, incorporating chemical recycling. Such a vision should clearly describe how scaling up these new technologies would enable the EU to reach its recycling targets, as well as create a virtuous circle where higher-quality recycled materials lead to further increases in recycled content in plastics.

Review and update waste legislation to include the latest recycling technologies. This adaptation should include the implementation of technical standards to ensure virgin-grade recycled polymers can be used in the same applications as corresponding virgin polymers. It should also cover standardized definitions and legal status (e.g. through end-of-waste criteria) to provide clarity on the nature and output of the technologies in scope, as well as on how they relate to other technologies in the waste hierarchy (see also Joint Research Centre, European Commission, 2014).

Set regulatory and/or fiscal measures to boost the use of recycled content. Fiscal incentives could include reduced VAT or lowered EPR fees, and regulatory measures could include a time-bound target for specific rates of recycled content. Such measures could include setting up a kind of trading scheme for recycling (and reuse) credits, comparable to the emissions trading scheme (ETS).

R&I framework initiatives

Provide funding to verify the economic and environmental impacts of feedstock recycling for industrial application through pilots and collaborative efforts. The verification should be based on a set of realistic boundary conditions, and allow comparison with other after-use pathways.

Provide funding for industrial piloting of solvent- based purification and depolymerization. As a first step, fund industrial pilot plants for depolymerization with a process capacity of 1 000 tons per year. A plant with such a capacity should be enough to assess the economic, environmental, and social impacts of the technologies. At the same time, it could provide enough material for the plastic converters to assess the performance for different applications, as these technologies will not take off without industrial validation. Pilots should also provide insights into the environmental and social impacts of, for example, processing the waste output, or of traces of solvents in the recycled material.

Provide funding for research to develop PMMA monomerization and solvent-based purification of PS and PC. This should happen through collaboration between academia, public research institutes and industry.

CONCLUSIONS

The European Union as well as the private sector move away from the current linear growth model to a circular one. It is important for organizations— regardless of market, geography or industry—to begin laying the foundation for change, that way they can initiate the transition to a new way of doing business that radically improves resource productivity, enhances differentiation, reduces costs and risks, creates robust new revenue streams, and enhances the customer value proposition. Rethinking the Plastics Economy is one the core issues of the circular economy transition. Plastics never become waste; rather, they re-enter the economy as valuable technical or biological nutrients. The New Plastics Economy is underpinned by and aligns with principles of the circular economy. Its ambition is to deliver better system-wide economic and environmental outcomes by creating an effective after-use plastics economy, drastically reducing the leakage of plastics into natural systems and other negative externalities; and decoupling from fossil feedstocks. Innovation and transition to the New Plastics Economy must be driven by joint, urgent, collaborative initiatives across industries and governments. This would make it possible to address the chronic fragmentation and the lack of global standards, to benefit the development of effective markets. In such an initiative, consumer goods companies, plastic packaging producers and plastics manufacturers would play a critical role as they define the products and materials that are put on the market. Cities control the after-use infrastructure in many places and are often hubs for innovation. Businesses involved in collection, sorting and reprocessing such as mechanical recycling of plastics are an equally critical part of the puzzle. Policymakers can play an important role in enabling the transition by realigning incentives, facilitating secondary markets, defining standards, and stimulating innovation.

Bibliography

[1] Ellen MacArthur Foundation, 'The New Plastics Economy: Rethinking the future of plastics', *Ellen MacArthur Foundation*, no. January, p. 120, 2016.

[2] J. M. Simon, Zero Waste Europe, F. Rosa, C. Allen, M. Wilson, and D. Moon, 'Changing trends in plastic waste trade: Plastic waste shipments report', no. November, 2018, [Online]. Available: www.zerowasteeurope.eu.

[3] P. Lacy *et al.*, 'Circular Advantage: Innovative Business Models and Technologies to Create Value in a World without Limits to Growth', *Accenture Strategy*, p. 24, 2014.

[4] I. Nishimura, 'Strategy for Plastics in a Circular Economy', *Seikei-Kakou*, vol. 30, no. 11, pp. 577–580, 2018, doi: 10.4325/seikeikakou.30.577.

[5] O. F. O. R. Innovation, M. Waste, M. Opportunities, C. Are, H. O. W. Do, and C. Feel, 'the Plastics How Do Consumers Feel ?', 2020.

[6] 'Strategic Research and Innovation Agenda (SRIA) European Open Science Cloud (EOSC)', no. February, pp. 1–195, 2021.

[7] P. Schroeder, K. Anggraeni, and U. Weber, 'The Relevance of Circular Economy Practices to the Sustainable Development Goals', *Journal of Industrial Ecology*, vol. 23, no. 1, pp. 77–95, 2019, doi: 10.1111/jiec.12732.

[8] P. Schroeder, K. Anggraeni, and U. Weber, 'The Relevance of Circular Economy Practices to the Sustainable Development Goals', *Journal of Industrial Ecology*, vol. 23, no. 1, pp. 77–95, 2019, doi: 10.1111/jiec.12732.

[9] European Commission, *A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions*. 2019.

[10] T. Clark, 'Plastics : Establishing The Path To Zero Waste', p. 131, 2015.

[11] G. James, 'An investor initiative in partnership with UNEP Finance Initiative and UN Global Compact THE PLASTICS LANDSCAPE: RISKS AND OPPORTUNITIES ALONG THE VALUE CHAIN', pp. 6–14, 2017, [Online]. Available: https://www.unpri.org/download?ac=10258.

[12] UNEP, *Plastics: A Roadmap for Sustainability*. 2018.

[13] Ellen MacArthur Foundation, 'The New Plastics Economy: Rethinking the Future of Plastics & Catalysing Action', *Ellen MacArthur Foundation*, p. 68, 2017, doi: 10.1103/Physrevb.74.035409.

[14] H. Rapp, D. Goodwin, H. Smith, M. Thorseth, and S. Koop, 'Expectations for the Circular Economy', no. 869318, pp. 1–54, 2021.

[15] P. Gaudillat, I. S. Antonopoulos, P. Canfora, M. Dri, European Commission. Joint Research Centre., and A. I. S, *Best Environmental Management Practice for the Waste Management Sector Learning from frontrunners*, no. May. 2018.

[16] D. Développement Durable, 'My-Risk-Blueprint-Plastics-Packaging-Waste-2017.Pdf'.

[17] K. H. Esbensen and C. Velis, 'Transition to circular economy requires reliable statistical quantification and control of uncertainty and variability in waste', *Waste Management and Research*, vol. 34, no. 12, pp. 1197–1200, 2016, doi: 10.1177/0734242X16680911.

[18] European Union, 'Report for European Commission DG Environment. Study to support the development of measures to combat a range of marine litter sources Incentivising Waste Disposal at Ports', no. January, 2016, [Online]. Available: http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/MSFD Measures to Combat Marine Litter.pdf.

[19] https://doi.org/10.1126/sciadv.1700782

[20] https://doi.org/10.1126/sciadv.1700782