VEOLIA INSTITUTE

THE VEOLIA INSTITUTE REVIEW

FACTS REPORTS

2019

REINVENTING PLASTICS

In partnership with

UNIVERSITY OF THE PACIFIC

THINKING TOGETHER TO ILLUMINATE THE FUTURE

THE VEOLIA INSTITUTE

Designed as a platform for discussion and collective thinking, the Veolia Institute has been exploring the future at the crossroads between society and the environment since it was set up in 2001. Its mission is to think together to illuminate the future.

Working with the global academic community, it facilitates multi-stakeholder analysis to explore emerging trends, particularly the environmental and societal challenges of the coming decades. It focuses on a wide range of issues related to the future of urban living as well as sustainable production and consumption (cities, urban services, environment, energy, health, agriculture, etc.).

Over the years, the Veolia Institute has built up a high-level international network of academic and scientific experts, universities and research bodies, policymakers, NGOs, and international organizations. The Institute pursues its mission through high-level publications and conferences, and foresight working groups.

Internationally recognized as a legitimate platform for exploring global issues, the Veolia Institute has official NGO observer status under the terms of the United Nations Framework Convention on climate change.

THE FORESIGHT COMMITTEE

Drawing on the expertise and international reputation of its members, the Foresight Committee guides the work of the Veolia Institute and steers its development.

The current members of the Foresight Committee are: **Harvey Fineberg**, President of the Gordon and Betty Moore Foundation and former President of the American Institute of Medicine; **Pierre-Marc Johnson**, international lawyer and former Premier of Quebec; **Philippe Kourilsky**, Honorary Director General of the Pasteur Institute; **Mamphela Ramphele**, former Managing Director of the World Bank; **Amartya Sen**, Nobel Prize-winning economist and Professor at Harvard University; and **Nicholas Stern**, Professor of Economics at the London School of Economics, Fellow of the British Academy and the Royal Society.

Review coordinated by Fanny Arnaud

THE REVIEW

The Veolia Institute Review - FACTS Reports is a high-level international publication compiling diverse perspectives on topics at the crossroads between society and the environment.

The review was launched in 2007 with the aim of sharing best practices from the field, to help find solutions to problems in the economy, development, healthcare, environment, agriculture and education, in both developing and developed countries.

The interdisciplinary review is a vehicle for sharing the experiences and expertise of different stakeholders (researchers, academic experts, policymakers, companies, NGOs, international organizations, etc.), with the aim of taking advantage of a diversity of perspectives on a given topic, by combining feedback on best practices from the field and expert analysis. The articles are subject to a reading committee prior to publication.

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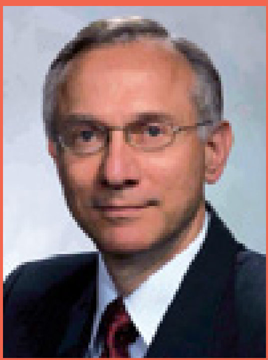
Harvey V. Fineberg - President of the Gordon and Betty Moore Foundation, Former President of the US National Academy of Medicine and Member of the Veolia Institute Foresight Committee



Mr. McGuire: I want to say one word to you. Just one word.
Benjamin: Yes, sir.
Mr. McGuire: Are you listening?
Benjamin: Yes, I am.
Mr. McGuire: Plastics.
Benjamin: Exactly how do you mean?
Mr. McGuire: There's a great future in plastics. Think about it. Will you think about it?
[Dialogue from the film, *The Graduate*, 1967.]

Plastics – versatile, flexible, strong, lightweight, durable, impervious to water, and inexpensive – are ubiquitous in modern life. In 1967, when the film, *The Graduate*, was released, worldwide plastic production hovered around 30 million metric tons. By 2016, global production had multiplied tenfold to 335 million metric tons, and if current trends continue, worldwide annual production will surpass 1,100 million metric tons by 2050[1,2]. It seems Mr. McGuire had a point: there was a great future in plastics.

Plastics made many things better. Lighter than metal, more durable than wood, moldable into any shape, rigid or flexible, plastics remade products and packaging. Industries as varied as automobile manufacturing, hardware, dry goods and groceries turned to plastic to reduce expenses, improve appearance, retain freshness and decrease pilfering. In modern hospitals, plastics appear everywhere from surgical suites to gurneys. Single use items, such as surgical gloves and intravenous bags and lines, reduce risk of contamination and eliminate the need for many sterilization procedures.

Nowhere is the disposable society more manifest than in the rise of plastic packaging. Today, packaging accounts for more than one quarter of all plastic production, and if current trends continue, packaging alone will amount to more than 300 million metric tons of plastic by 2050. Today, only 14% of plastic packaging is collected for recycling (compared to 58% of paper and 70-90% of iron and steel) and, with losses from resorting and processing, only about 1/3 of that actually makes its way into a new product. Thus, 95% of plastic packaging material, valued at $80 to $120 billion, is lost to the economy shortly after its first use[1].

Especially worrying are environmental impacts of discarded or leaked plastic, degradation of natural systems, and pollution. On land, in rivers and at sea, plastic litter is unsightly and wreaks havoc on ecosystems. Plastic dumped in the ocean deleteriously affects tourism, fishing and shipping. Altogether, an estimated 8 million tons of plastic leak into the ocean every year[1].

Plastic can persist for hundreds of years in the oceans. Depending on the specific polymer, density and composition, many sea-borne plastics will eventually degrade into micro-particles or fibers, which in turn can persist even longer. Today, an estimated 150 million tons of plastic pollute the world's oceans, and the amount cumulates with every additional leakage. If current trends continue, by 2050, seaborne plastic will weigh as much as all the fish in the ocean[1].

Micro-plastics in the ocean are finding their way into and up the food chain, with uncertain implications for human health[3]. One recent study found 90% of samples of sea salt contaminated with micro-plastic, and the amount correlated with density of ocean plastic in different parts of the world[4].

Reducing ocean contamination with plastics deserves urgent action by governments, industry and consumer groups in all parts of the world. Moving plastics from the disposable society into the circular economy is the only sustainable way forward. This begins with reducing waste of plastic and improving efficiency of production, continues with designing plastic products to be more readily compostable and recyclable (for example, eliminating mixed plastic types in bottles and caps), benefits from technological advances in processing and recycling facilities, and requires pathways for re-use of plastic products. Specific efforts to protect sea life and reduce the burden of plastic in oceans will require greater awareness of the scope of the problem, scientific research, technological ingenuity, economic incentives and political determination. Plastic in the oceans is a classic case of the tragedy of the commons, where individuals acting in their independent self-interest collectively degrade the value of a shared resource[5].

This issue of The Veolia Institute Review - FACTS Reports portrays the history, uses and future of plastics in revealing and important ways. If plastics can gain a firm place in the circular economy, then we can give new meaning to Mr. McGuire's declaration more than fifty years ago, and there will be a great future in plastics.

1 The new plastics economy: rethinking the future of plastics. World Economic Forum, 2016. (http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf)
2 Plastics—the facts 2017. Plastics Europe. (https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf)
3 Smith M, Love DC, Rochman CM and Neff RA. Microplastics in seafood and the implications for human health. *Curr Environ Health Rep.* 2018; 5(3): 375-386.
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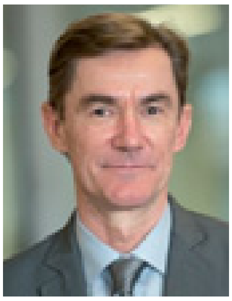
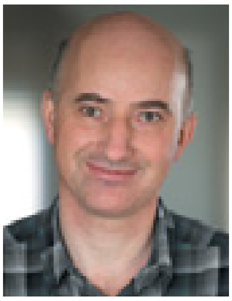
5 Hardin G. The Tragedy of the Commons. *Science.* 1968; 162(3859): 1243-8.

INTRODUCTION

David Ojcius - Professor, University of the Pacific
Nicolas Renard - Director of Foresight, Veolia Institute





Plastics are yesterday's hero and today's villain – their fall from grace precipitated by their success. As with many materials, plastics were perfectly acceptable as long as their use remained marginal. But now that plastics have conquered the planet, their use has become a problem. After cement and steel, plastics are the third most-widely manufactured material in the world. And production of plastics will continue to grow in the decades ahead, driven by demand from emerging and developed economies alike.

This is bad news for the environment, unless we find ways to improve the management of end-of-life plastics, which generate high volumes of waste that degrade extremely slowly in nature. A symbol of modernity, plastics have become ticking time bombs that threaten human and environmental health. A major factor is the paradox of the life cycle of plastics: designed to last for a very long time but used only briefly, almost half of all plastics are turned into packaging that is discarded almost immediately after the product is purchased.

The plastic life cycle is paradoxical. Plastics are designed to last but are used only briefly.

Plastics are all around us: in toys, household appliances, sports equipment, classroom supplies, medical equipment, as well as every trash can, every outdoor space and every sea and ocean. The challenge is how to remove the scourge of plastics from the economy and the environment. We cannot do without plastics completely, but we can restrict their use to vital applications for which no substitute exists. Many countries are already implementing legislation to curtail the use of single-use plastics.

But the real solution lies in the circular economy, which converts waste into a valuable resource. Despite the omnipresence of plastics, very few plastics are recycled. Worldwide, no more than 9% of plastics are recycled; compared to 80% of ferrous metals, 60% of paper and 50% of glass that are recycled. And yet the potential benefits of recycling are immense: by reducing waste of raw materials, overexploitation of nature and environmental pollution as well as limiting global warming. This is because recycling plastics can dramatically reduce greenhouse gas emissions, with five barrels of oil saved for every metric ton of plastic recycled.

Which raises the obvious questions: why are plastics so under-recycled, why do so many plastics end up in nature? The answers: a lack of infrastructure for collecting and processing plastics, particularly in developing economies; limitations of current technologies; consumer reluctance to use recycled plastics, especially when used in the food industry; the supply of inexpensive crude oil, which makes it cheaper to manufacture plastics than to recycle them; and the difficulty in meeting the demands of consumers in terms of quality, availability and price. All this means that recycling cannot progress unless we find ways to scale up collection and reprocessing of plastics to offset the high cost of recycling installations, coupled with regulatory or financial mechanisms to incentivize manufacturers to use regenerated resins.

Recycling also requires appropriate eco-design as products can only be recycled if they are designed to be recyclable! This goal is not helped by the plastic industry's sheer creativity: plastics are formed from a wide variety of resins, additives and mixtures for a seemingly limitless list of uses, all of which makes recycling a complicated affair. This means that while eco-design remains voluntary, many plastics cannot be recycled cost-effectively. Combatting this 21st century pollution will require a major paradigm shift. In the past, plastics were made to last – in the future, we need polymers that biodegrade quickly or can be recycled. It is by examining the whole life cycle of plastics that we can extend their usefulness as a resource, and reduce the time they spend as waste.

Thus, acting upstream and on land, we can conquer the overabundance of plastics afflicting the planet's waterways and oceans. The task is titanic, but it is achievable in the long term, since only 10 rivers account for 90% of plastic waste entering the world's oceans.

A final point can be made when considering the turbulent history of this material, which represents one of the 20th century's main industrial revolutions. If people were to stop throwing away plastics as litter, the plastics would not make their way to the sea. Plastic pollution is also a consequence of our behavior as individuals. Whether through our day-to-day actions or initiatives led by non-profits and business, we must all play our part in deplastifying our lives.

1. PLASTICS: FROM APOGEE TO CONTROVERSY

Beach covered in litter, Muncar, Indonesia - ©Project STOP

A century after plastic was invented, its properties – being lightweight, strong and cheap – have swept it into every corner of our throwaway society, from food to health, automotive to fashion. The amount of plastic produced worldwide has grown exponentially, from 1.5 million metric tons in 1950 to 335 million metric tons in 2016. It has also created wealth, with plastics accounting for over 1.5 million jobs in Europe and contributing €27.5 billion to European public finances.

Initially a symbol of modernity, in recent years plastic has undergone a rapid and far-reaching re-examination of its role in our lives around the world. Latest scientific estimates are that the world's oceans contain 150 million metric tons of plastic waste, of which 62% is packaging. This planet-wide pollution imperils an essential common good that is at the center of our global system. The oceans are a vast reserve of fish resources, a carbon sink and a source of oxygen production; they produce 50% of our oxygen and absorb a third of all CO_2 produced on earth, and over 3 billion people depend on marine and coastal biodiversity for their livelihoods.

Why this change of fortune?

As early as the 1970s, scientists were already flagging concerns about the adverse impacts on marine environments of small plastic waste particles: ingestion by animals, strangulation, obstruction and so on. Despite these early warnings, the issue remained little known until the discovery of ocean gyres – systems of circulating currents where high volumes of plastic waste accumulate – raised awareness on a far wider scale.

At the same time as scientists took an increasing interest in studying the impact of plastic pollution on human health and the environment, a number of NGOs such as WWF and the Ellen MacArthur Foundation took up the issue, seeking to alert the public and governments to the dangers posed by plastic pollution.

Unlike other worldwide environmental problems, such as greenhouse gas emissions, plastic pollution is visible. Images on social and mainstream media of marine animals strangled or trapped by plastic waste have catalyzed the recent wave of emotionally driven mass mobilization.

Recently, this mobilization has led to questions being raised about industries' license to operate, with fingers being pointed at plastic packaging and products on the market. Recent plastic attacks on a number of supermarkets in the United Kingdom and in France are good illustrations of how this grassroots movement seeks to alert consumers to excessive packaging and place pressure on industries. Everywhere, from oil and gas to food to fashion (60% of clothes are made from plastics), these challenges are driving manufacturers into overly hasty undertakings about using plastic more virtuously.

At the same time, governments too are grappling with the issue and regulating to ban certain products, such as the European Commission's proposed ban on single-use plastic products, and to promote recycling. Worldwide, there are enormous disparities in recycling between developed economies with good infrastructure, and developing economies, in Southeast Asia especially, where inadequate infrastructure means that most waste ends its life in nature or the sea. As Kabadiwalla Connect explains, the informal sector plays a fundamental role in recovering waste in cities in developing economies. Worldwide, less than 2% of plastic used is recycled in a closed loop, a figure that illustrates how much remains to be accomplished.

Fanny Arnaud
Review coordinator

THE HISTORY OF PLASTICS: FROM THE CAPITOL TO THE TARPEIAN ROCK

Philippe Chalmin
Professor, Paris-Dauphine University

A graduate of the HEC business school, holder of the *agrégation* in history, and a Doctor of Literature, Philippe Chalmin is Professor of Economic History at Paris-Dauphine University where he directs the Masters in International Affairs. He is the founding chairman of Cyclope, the main European institute for research into raw material markets, which publishes the annual Cyclope Yearbook on the economy and global markets.

KEY WORDS

- PLASTICS ECONOMY
- PLASTICS MARKET
- PRODUCTION
- INDUSTRY

Few industries like plastic have experienced similar growth in the space of 60 years, both in terms of production tonnage and use in virtually every moment of our daily lives.

However, plastic is now victim of its own success. Waste is piling up, collection struggles to keep up, recycling is costly... With everyone pointing a finger at it, plastic is more than ever at the center of society's debates.

While people in the most developed countries are now clearly aware of the problem, in emerging and developing economies this awareness is hampered by problems of urban governance attributable to the rampant population growth in the megacities.

Plastic has unwittingly become a symbol of the crisis of our postmodern society and one of the major challenges of the 21st century - albeit far from the only one. These problems need to be addressed pragmatically, with our eyes wide open, and without any illusion that we can achieve a plastic-free world.

INTRODUCTION

"Product invented in the early 20th century, reached its peak some 100 years later and whose eradication will be one of the major challenges of the 21st century." Crossword lovers will no doubt recognize this seven-letter clue to a family of products that will go down in history as one of the symbols of the second half of the 20th century. But to predict its eradication in the decades ahead is perhaps to jump the gun, given the extent to which plastics are part of our everyday lives from the simplest to the most complicated and sophisticated uses.

A BRIEF HISTORY OF PLASTICS

Leo Hendrik Baekeland seems to have been the first person to use the term "plastic materials" to describe products made from macromolecules (resins, elastomers and artificial fibers). That was in 1909. Two years earlier, he had invented the first synthetic plastic: bakelite. Telephones were made of this material for many years. In fact, plastic had been invented well before then. In 1833, Frenchman Henri Braconnot had produced nitrocellulose, which the Hyatt brothers manufactured industrially in the United States from 1868 to make billiard balls. And so plastic started its long career as an "imitation" – in this case, to replace ivory. But as it was manufactured from cellulose, we were still not in the realm of synthetics.

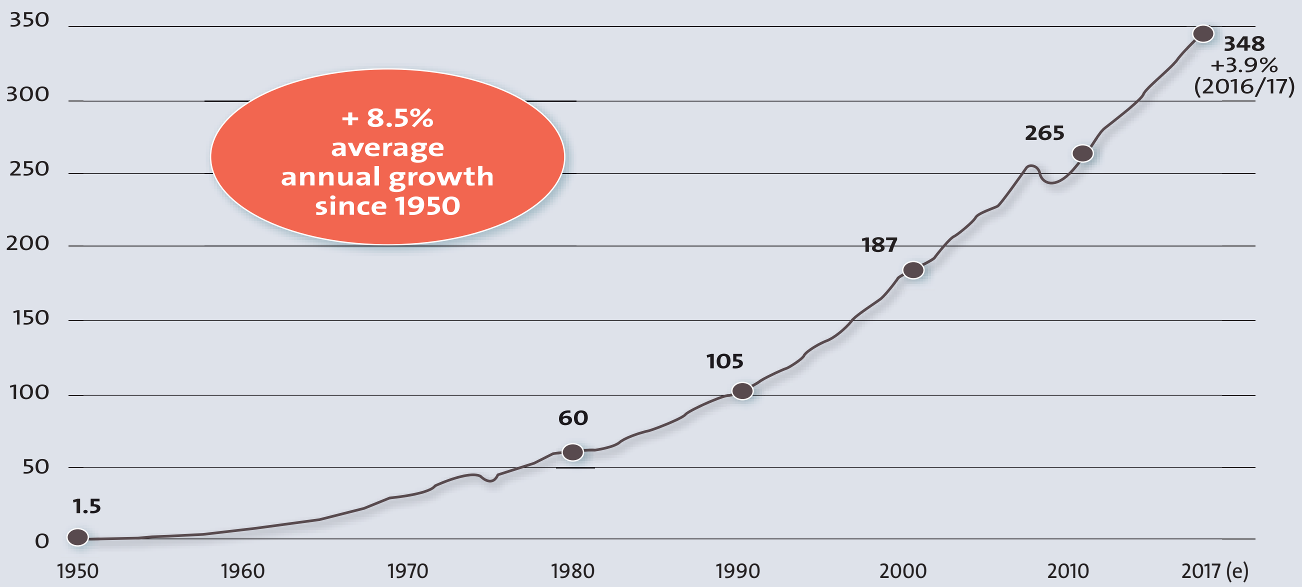
"Product invented in the early 20th century, reached its peak some 100 years later and whose eradication will be one of the major challenges of the 21st century."

The main inventions in the world of plastics occurred between the two World Wars: cellophane in 1913, then polyvinyl chloride in 1927, polystyrene and nylon in 1938, and polyethylene in 1942. A few years later, philosopher Roland Barthes said: "Despite having names of Greek shepherds, plastic [...] is in essence the stuff of alchemy."

The alchemy here was in fact written in the decades following World War II. Between 1950 and 1970, production increased twentyfold to more than 25 million metric tons. At the time, it was concentrated in the West: 8 million metric tons in the United States, 4 million in Japan and England, 1.3 million in the UK, Italy and France. The USSR – still the world's second largest economy – produced only 1.45 million metric tons. During these prosperous years, when the West turned its back on the Depression and wars, plastics burst into our everyday lives. A symbol of the "American way of life", Tupperware first appeared in 1946. In the early 1950s, the Italian chemical engineer Giulio Castelli molded the first plastic draining rack. Ten years later, Roland Barthes devoted one of his "Mythologies" to plastic: "Plastic has climbed down from its pedestal, it is now a household material [...] the whole world can be plasticized." And so it quickly was: plastic even had its hour of glory in the world of haute couture (Courrèges) and "hip" furniture in the 1960s. We remember Benjamin, the hero of the "The Graduate," receiving a single word of advice from his father's friend: plastic, the material of the future.

The first plastic bottles appeared in 1968 (Vittel mineral water in France). In 1980, the world produced 60 million metric tons of plastic. By 2000, production reached 187 million metric tons, then 265 million in 2010 and 348 million in 2017. That is an average growth rate of 8.5% per year since 1950 when it was 1.5 million metric tons. Today, China accounts for one-third of global production, a lower proportion than for other basic industries such as steel and aluminum. Since 1950, 8.3 billion metric tons of plastic have been produced. In a 2018 study, the International Energy Agency predicts production of around 600 million metric tons by the middle of the century.

Global plastic production (million metric tons)



No other industry in the world has experienced such growth. By way of comparison, global production of steel rose from 600 to 1,700 metric tons between 1980 and 2017 and aluminum from 14 to 60 million metric tons.

Source: PlasticsEurope Market Research Group

KEY DATES IN THE HISTORY OF PLASTIC

1907 - Bakelite
Leo Baekeland created the first entirely synthetic resin: bakelite, which, when heated, rapidly takes the shape of its container. This multipurpose material – a thermosetting plastic – doesn't burn, boil or melt and is not dissolved by solvents. Aware of its qualities as an electrical insulator, industry started to use it back in 1920 to manufacture telephones and the first household appliances.

1912 - PVC
Polychloride vinyl was discovered in 1835 by the French physicist Victor Regnault. The German professor Fritz Klatte developed manufacturing processes enabling its industrial development from 1912.

1913 - Cellophane
In 1900 a researcher, Edwin Brandenberger, had the idea of creating transparent packaging for food. He used viscose to develop cellophane, the first perfectly watertight flexible film that went on to have innumerable applications in everyday life.

1924 - PMMA (Plexiglas)
Chemists Barker and Skinner created an organic glass, Poly(methyl methacrylate) (PMMA), which was sold by Rohm in 1934 under the name of Plexiglas. Appreciated for its transparency and strength, it is used for illuminated signs, furniture, etc. Its two most famous brand names – Plexiglas and Perspex – have become household names.

1933 - Polyethylene (PE, PE-HD, PE-MD, PE-LD, PE-LLD)
The discovery of low-density polyethylene was the result of research on resins by E.W. Fawcett and R.O. Gibson. The most commonly used plastic in the world, polyethylene has an extremely wide variety of uses from military applications to the manufacture of shampoo bottles.

1937 - Polyurethane (PUR)
When Dr. Otto Bayer developed polyurethane, no one could have imagined the success that it would have. Since then, following the work of several generations of chemists, developers, engineers and designers, it has become a universal material.

1938 - Nylon (Polyamide 6.6)
The synthetic fiber developed in the 1930s by a team of researchers led by the chemist Wallace Carothers was given the name Nylon by DuPont de Nemours. It is a super polyamide that forms very strong elastic threads that resist atmospheric agents and do not rot. Nylon was to prove itself in GIs' parachutes before going on to revolutionize the textile industry after World War II.

1944 - Polystyrene (PS, PS-E)
Expanded polystyrene was developed in 1944 by Ray McIntire, who was working for Dow Chemical on flexible rubber. It was discovered by chance. The initial idea was to copolymerize styrene and isobutene under pressure. Only the styrene polymerized and the isobutene vaporized into the polymer matrix. Sold under the name Styrofoam, this rigid, low-density material was initially used as thermal insulation for buildings.

1954 - Polypropylene (PP)
Working for Montedison, Giulio Natta (1963 Nobel Prize with Karl Ziegler) discovered a catalyst in what is dubbed the "Ziegler-Natta" family that was able to produce polypropylene with high mechanical resistance, was inert to chemical aggression and able to withstand temperatures above 100 °C.

Source: Plastics Europe

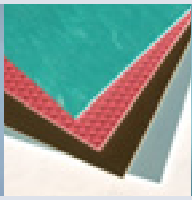
THE PLASTICS ECONOMY

For the most part, with the still marginal exception of bioplastics, plastic is part of the petrochemical industry and is produced from oil, refined into naphtha, or from natural gas. In 2016, the petrochemical industry used the equivalent of 17.4 million barrels of oil per day, which is just under 20% of global oil consumption. The major producers have historically been oil groups (Shell, Aramco, etc.), and chemical companies that often separated their heavy and fine chemicals businesses. It is a very capital-intensive business in a particularly unstable environment, whether for the upstream market (oil and gas) or the downstream markets (commodities). For the latter, the main semi-finished products are markets in their own right and some, in China, even have futures markets.

Some everyday plastic cult items

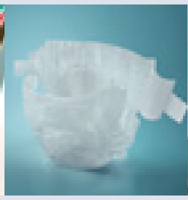
NYLON BRISTLE TOOTHBRUSH

In 1937, Wallace H. Carothers, at DuPont de Nemours, developed polyamide 6.6, better known as nylon. Used a year later to replace boar hairs, this synthetic fiber marked a turning point in the history of toothbrushes.



PVC FLOORING

In 1949, manufacturing company Gerland used PVC for the first time to make a floor covering.



DISPOSABLE DIAPER

Designed in the 1950s by Procter & Gamble, the plastic disposable diaper went on sale 10 years later.

UPRIGHT VACUUM CLEANER

The first upright vacuum cleaner manufactured entirely from nylon was sold by Moulinex in 1961.

PLASTIC BOTTLE

In 1968, Vittel took the revolutionary step of producing its first plastic bottle. It weighed 36 g compared with 300 g for a glass bottle and contained 1.5 liters of water.

BANK CARD

Traditional bank cards were revolutionized by the arrival of the microchip invented by Roland Moreno. This small PVC or polypropylene card was to become an essential payment method.

DISPOSABLE RAZOR

After the Bic© ballpoint pen, in 1975, Marcel Bich invented the disposable plastic razor. Several million of these are still sold every day throughout the world.

Packaging is still the main outlet for plastics (150 million metric tons) followed by building and construction (60 million metric tons, accounting for 40% of use in the European Union and as much as 46% in France), textiles (55 million metric tons), consumer goods, the automotive sector and electronics. Plastics are an integral part of our everyday lives. A UN report estimated that 500 billion plastic bags are used each year, which is 10 million every minute! The yearly per capita consumption of plastic is close to 100 kg (2015) in South Korea and Canada; 80 kg in the United States, 60 kg in Western Europe, 45 kg in China, but just 10 kg in India and 5 kg in Africa.

One of the characteristics of plastic, especially in the packaging sector, is that its period of use can be extremely short. Plastic is generally used only once then thrown out, potentially to be recycled. Roland Geyer at the University of California, has calculated that of the 8.3 billion metric tons of plastic produced since 1950, 5.8 billion were thrown out

European plastics converter demand by polymer types in 2016

Data for EU28 + NO/CH

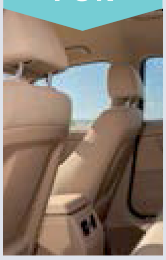
6.7% — **PS, PS-E**

Eyeglass frames, plastic cups, egg trays (PS); packaging, building insulation (PS-E), etc.

7.4% — **PET**

Bottles for water, soft drinks, juices, cleaners, etc.

7.5% — **PUR**



Building insulation, pillows and mattresses, insulating foams for fridges, etc.

10% — **PVC**

Window frames, profiles, floor and wall covering, pipes, cable insulation, garden hoses, inflatable pools, etc.

12.3% — **PE-HD, PE-MD**

Toys, (PE-HD, PEMD), milk bottles, shampoo bottles, pipes, houseware (PE-HD), etc.

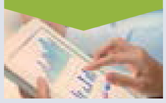
17.5% — **PE-LD, PE-LLD**

Reusable bags, trays and containers, agricultural film (PE-LD), food packaging film (PE-LLD), etc.

19.3% — **PP**

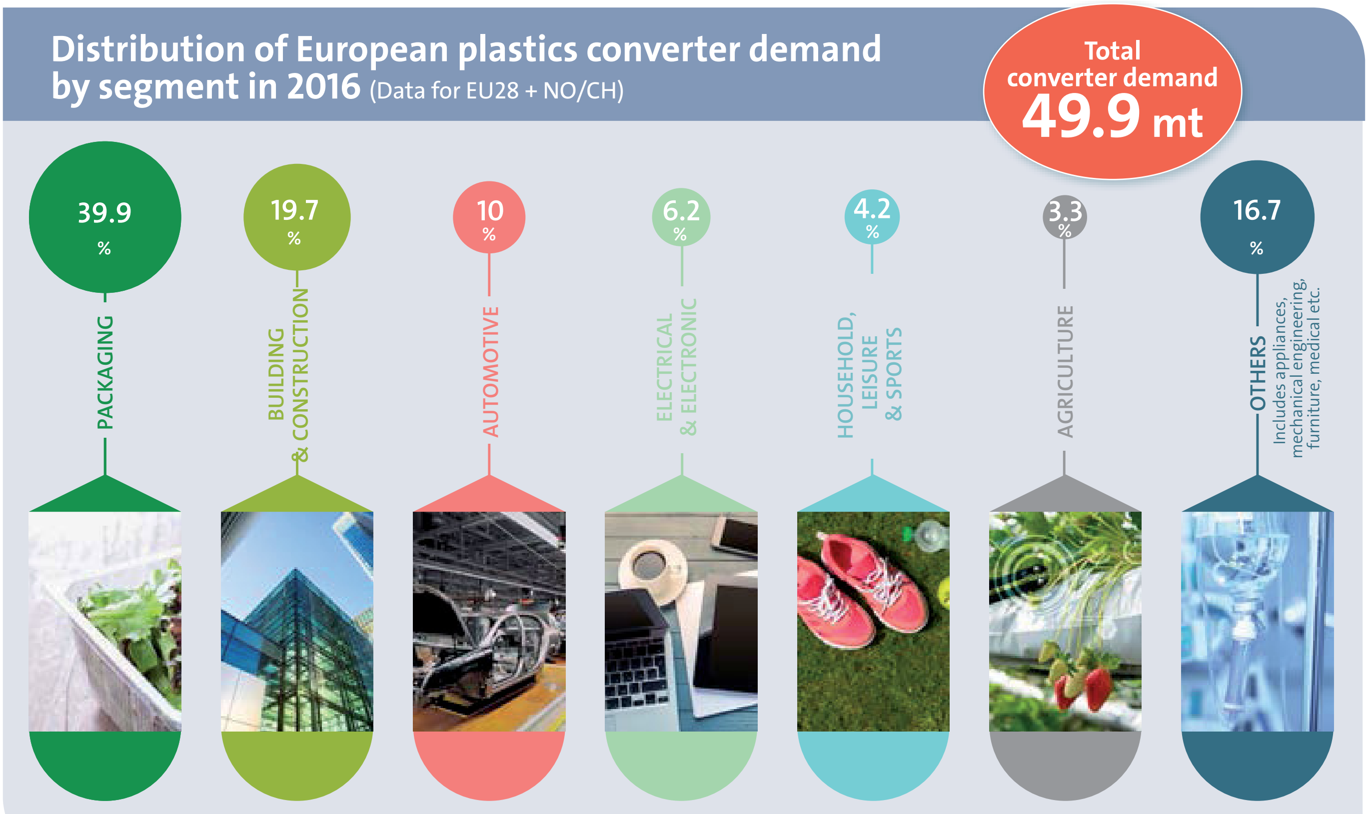
Food packaging, sweet and snack wrappers, hinged caps, microwave-proof containers, pipes, automotive parts, bank notes, etc.

19.3% — **OTHERS**



Hub caps (ABS); optical fibers (PBT); eyeglass lenses, roofing sheets (PC); Touch screens (PMMA); cable coating in telecommunications (PTFE); and many others in aerospace, medical implants, surgical devices, membranes, valves & seals, protective coatings, etc.

Source: PlasticsEurope Market Research Group (PEMRG) and Conversio Market & Strategy GmbH



Source: PlasticsEurope Market Research Group (PEMRG) and Conversio Market & Strategy GmbH

and of that amount, 500,000 metric tons were recycled and 700 metric tons incinerated. That leaves 4.6 billion metric tons somewhere in the environment, especially in the oceans.

A recent study by the World Bank estimated that of the 2 billion metric tons of waste produced worldwide in 2016 (and this figure only includes household waste), 242 million metric tons were plastic, 57 million metric tons were in Asia, 45 million metric tons in Europe in its broadest sense, and 35 million metric tons in North America. Equated to global production of 336 millions metric tons, this means that the equivalent of 70% is thrown out each year.

This raises a sensitive issue: compared with paper, scrap metal and glass, the recovery rate for plastic is still low, because it is directly linked to the collection rate for the waste in which it is generally mixed. While waste collection – in particular for household waste – has reached an undeniable level of maturity in developed countries, with increasingly selective collection, the same cannot be said for the rest of the world which, as we have seen, has accounted for the bulk of the growth in demand for plastic in the past 30 years. A German study published in 2017 estimated that ten rivers, of which eight are in Asia and two in Africa, account for 90% of plastic waste in the oceans – the Yangtse alone releases 15 million metric tons each year. The problem here is less one of plastic itself than that of the waste collection systems, whether formal or informal. The mountains of waste in non-regulated dumps are haunted by waste pickers who are often less efficient in collecting plastic, which is sometimes as light as the wind.

Even in developed countries, recycling is still very limited and incineration does not get a very good press. The European Union, which consumes 49 million metric tons of plastic, has a recycled material usage rate of around 6%, which represents a little less than 3 million metric tons. The European Commission estimates that Europe generates almost 26 million metric tons of plastic waste, of which 31% is recycled (in Europe or elsewhere, such as China, which imported waste until 2017), 42% is incinerated and 27% ends up in landfills. However, it is a fact that virgin plastic will continue to be largely unavoidable even if some of its uses can be limited.

PLASTIC: A CORE POLEMIC

Plastic has become a problem for society. We are far from the day when Roland Barthes saw it as “a miraculous material”. On the contrary, it is at the center of considerable polemic as demonstrated by a recent television program in France in which the “Cash Investigation” reporters demonstrated their usual over-simplistic approach in addressing the topic. Their conclusion was that the evil multinationals do all they can to ignore the benefits of the circular economy – and many NGOs that struggle to communicate rushed headlong into the debate because it's a subject that directly concerns the general public. Many right-thinking people are now pointing the finger at plastic, as illustrated by a recent article in the French news weekly *L'Obs*: "Tomorrow I'm stopping."[1]

To condemn plastic out of hand is of course absurd. For some of its uses, it has proven its economic and also environmental competitiveness (in terms of its carbon footprint). It has the undeniable advantage of being lightweight and able to replace some products (wood, paper and metal) which, while being more "natural," are often more expensive and have an equally high carbon footprint.

Several types of plastic products have been attacked or made subject to regulations. These are generally single-use products that are thrown out after having been used. The most obvious of these is the plastic bag, now banned in France along with Bangladesh and Rwanda. It is true that they make up the bulk of the "seventh continent" floating semi-submerged in the oceans. Then, there are PET bottles for which major corporations like Coca-Cola have, as yet, very limited commitments. Plastic straws have recently come under attack, to the extent that Tetra Pak has committed to replacing them with paper straws. Such a use may seem marginal until you realize that a country like France throws out 8.8 million of them every day. The European Union is considering introducing a ban in 2021 of 10 single-use products including straws, plastic cutlery and plates, and cotton buds. In France, there has also talk of banning PVC doors and windows in the construction industry.

Over and above reducing the consumption of plastic, which many observers are skeptical about (Wood Mackenzie does, however, anticipate peak single use of plastic in the 2020s and BP is talking about a drop in the global use of plastic by 2% toward 2040), the other strategy involves better collection and recovery of plastic waste.

In January 2018, the European Commission published its "plastics strategy". Its aim is to incorporate 10 million metric tons of recycled plastic into new products within the – very short – timeframe of 2025. This will mean at least tripling the level of current recycled content while also taking into account the fact that by then production will probably have increased further. Plastic-consuming companies will have to present the Commission with their plans for including recycled plastic. This will of course increase the demand for recycled plastic, which – it is to be hoped – will fund this "strategy", estimated to cost around €6 billion.

The balance of the European market for "old plastic" is fairly subtle and due to insufficient demand, it often depends on exports. The Chinese outlet is now closed (Chinese imports fell from 7.3 million metric tons in 2016 to 1.5 million metric tons in 2018), while in 2018, there was some traffic toward Turkey. However, plastic waste is currently a negative revenue stream.

In France, the aim of the circular economy roadmap is to achieve 100% recycled plastic by 2025, which would seem to be a senseless goal given that France currently recycles only 22% of its plastic waste. Also, it is not sure that this target is totally "carbon consistent" when taking into account the logistic requirements and the fact that energy recovery through incineration can be an optimum solution for some types of plastic.

Some are, however, raising their voice to bring some perspective into the debate about plastic's harm, notably compared to other types of pollution and global issues such as climate change. Trucost, an analytical company and subsidiary of Standard and Poor's, puts the environmental cost of plastic at $139 billion per year, half of which is attributable to the greenhouse gases emitted for its manufacture and the other half for the other effects (health and pollution) and the cost of recycling. It is a significant amount but it brings into perspective the pollution caused by plastic, even if from a media point of view, it is a promising theme.

In any event, the problem of managing "secondary plastic" is no closer to being solved, from collection to final recovery, and starts at the level of households and individuals, as emphasized by the World Bank.

FUTURE OF A YOUNG INDUSTRY

Compared to other longstanding industries, the plastic industry is very young. In just a few decades, this family of ever-changing products has become central to our daily lives, and essential for some extremely sophisticated applications. Awareness of the fact that we have now gone too far was late in coming and is still too limited, given the scope of the problem. While older industries, like paper and metallurgy, have had time to adapt (and moreover they involve products that are easier to collect and recover), plastic actually suffers from its own flexibility and lightness. While people in the most developed countries are now clearly aware of the problem, in emerging and developing economies this awareness is hampered by problems of urban governance attributable to the rampant population growth in the new megacities.

We should reach peak plastic about one century after this "young" industry took off. Even so, the mountains of waste will continue to fill land and sea if a sizeable effort is not made to at least start to reduce single use and organize collection, recycling and energy recovery.

In any event, plastic, the material that so fascinated Roland Barthes, has unwittingly become a symbol of the crisis of our postmodern society and one of the major challenges of the 21st century – albeit far from the only one. These problems need to be addressed pragmatically, with our eyes wide open, and without any illusion that we can achieve a plastic-free world.

1 L'Obs, May 2018

PLASTICS RECYCLING WORLDWIDE: CURRENT OVERVIEW AND DESIRABLE CHANGES

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Veolia, Germany - Rostock, ©Veolia Picture Library / Alexis Duclos

Veolia designs and provides water, waste and energy management solutions that contribute to the sustainable development of communities and industries. In 2017, Veolia recovered 47 million metric tons of waste. The Group has set itself a target of increasing its revenue from recycling plastics (excluding collection and sorting) from €200 million to €1 billion by 2025, primarily in Europe and Asia.

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KEYWORDS

- PLASTICS ECONOMY
- RECYCLING
- REGULATION
- ECO-DESIGN

Plastic is one of the world's most-used materials. Technically sophisticated, lightweight and cheap, plastics suit a broad spectrum of uses. The problem with plastic lies not in how it is used, which is generally harmless, but in end-of-life management of products made from it. Since 1950, close to half of all plastic has ended up in landfill or dumped in the wild, and only 9% of used plastic has been adequately recycled. Every year, it is estimated that 4 to 12 million metric tons of plastic waste ends up in the oceans[1]. How plastic waste is processed remains extremely variable from country to country, and recycling remains considerably under-used. On the one hand, developed economies with regulations that encourage it have recycling rates around 30%. On the other hand, developing economies with a minimal industrial base have recycling rates close to 0%. And yet recycling is the best solution for processing plastic waste because it limits environmental impact and generates significant socioeconomic gains. However, at every stage of the plastic life cycle, there remain a large number of impediments to the development of recycling. By taking steps to promote recycling, manufacturers of plastic products, regulators, waste managers and consumers can all exert significant influence on the development of the recycling sector.

INTRODUCTION

Plastics are one of the world's most-used materials. As its name suggests – from the Greek plastikos meaning capable of being shaped or molded – plastic can adopt any shape or form. This is why it is used for such a wide variety of applications, from everyday single-use products like packaging and bottles to products that last for years, such as furniture, clothes, building materials and automotive components. Plastics have replaced a wide range of traditional materials including glass, steel, wood, and even concrete. Plastics weigh less, cost less and offer outstanding technical properties.

The rise of plastic coincides with the years of post-World War II prosperity and the burgeoning consumer society. French intellectual Roland Barthes celebrated it in his 1957 book Mythologies. "So, more than a substance, plastic is the very idea of its infinite." He also made this prophecy: "The hierarchy of substances is abolished, and a single one replaces them all – the whole world can be plasticized and even life itself since, we are told, they are beginning to make plastic aortas."

The amount of plastic used has indeed grown constantly over the past 30 years, reaching over 300 million metric

1 Jambeck, Geyer, Wilcox, Siegler, Perryman, Andrady, Narayan, Law. *Marine Pollution. Plastic Waste Inputs from Land into the Ocean*, Science, Feb 13, 2015

tons in 2017[2]. This growth is set to continue, driven in large part by the demands of the Chinese and Indian middle-classes; demand may double by 2050[3].

The problem with plastic lies not in how it is used, which is generally harmless, but in end-of-life management of products made from it. The fact is that since 1950, only 9% of plastic used has been adequately recycled[4] and close to half has ended up in landfill or dumped in the wild. It is thought that every year around 8 million metric tons of plastic waste ends up in the oceans[5], swept along by the world's rivers. In addition to being a critical environmental problem, lack of recycling represents a tremendous amount of value that local economies fail to capture.

2 Plastics Europe, *Plastics – The Facts*, 2017

3 International Energy Agency

4 Roland Geyer, Jenna R. Jambeck and Kara Lavender Law. Production, Use, and Fate of all Plastics ever Made, Science Advances, July 19, 2017

5 Jambeck, Geyer, Wilcox, Siegler, Perryman, Andrady, Narayan, Law. *Plastic Waste Inputs from Land into the Ocean*, Science, Feb 13, 2015

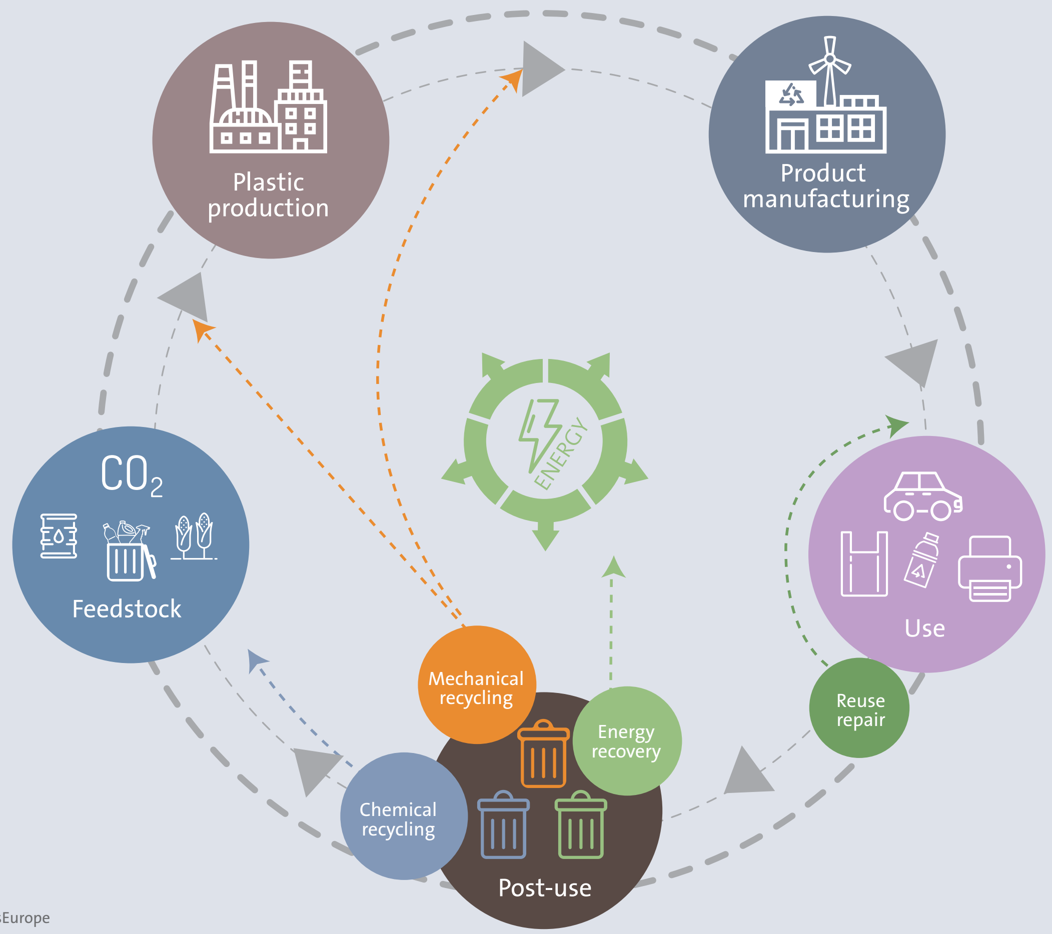
CURRENT SITUATION: COMPLEXITIES AND DISPARITIES IN PLASTIC WASTE MANAGEMENT

THE ECONOMY OF PLASTIC: A MULTITUDE OF STAKEHOLDERS INVOLVED

Over 90% of raw plastic is produced from fossil fuels (oil or natural gas). The polymers are synthesized by major petrochemical companies like ExxonMobil, Sinopec and Total. The plastic is then sold to plastic manufacturers to make objects, mostly by injection, blow molding or heat forming. These objects are then assembled or sold directly by brand owners via a range of retail circuits.

Take the example of a bottle of mineral water. The plastic will come from a petrochemical PET producer, Indorama for example, and then goes to a preformer to create a preform, an intermediate stage in the manufacture of the bottle. The preform is then blown into a bottle in a mold, and only then does a mineral water company like evian® fill it with water. Now it can be released into the market and sold, for example in a supermarket.

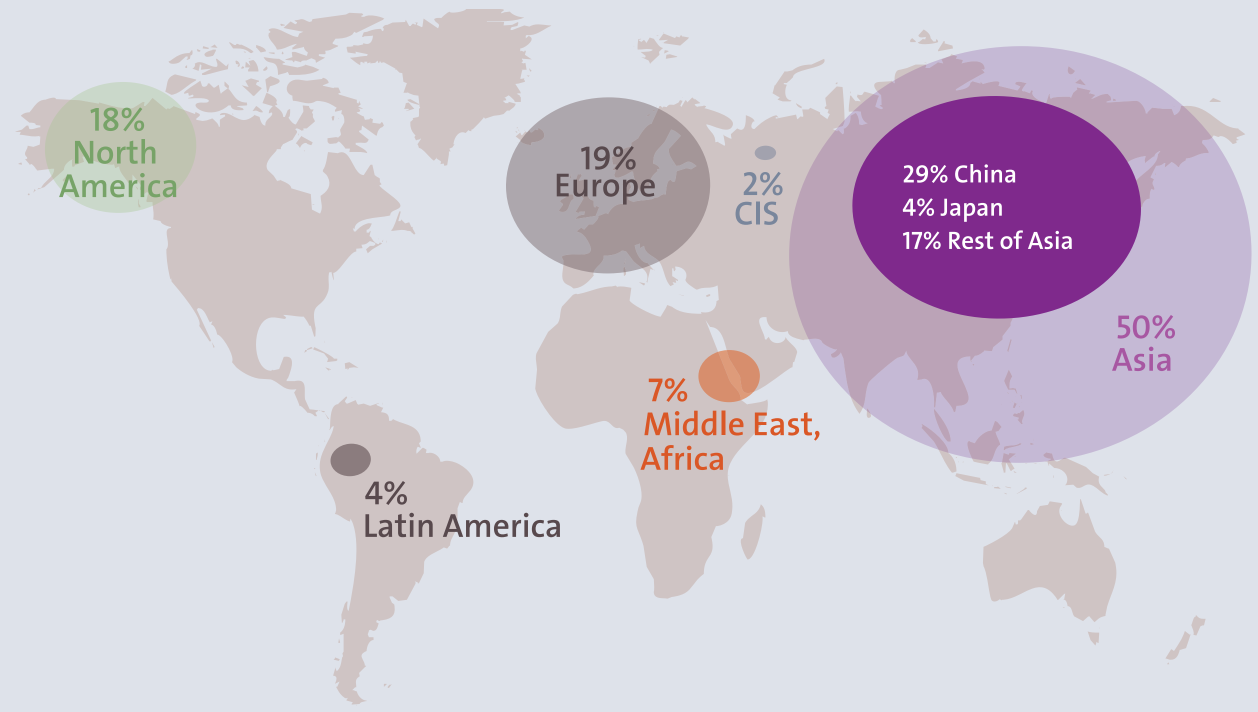
Plastics life cycle



Source: PlasticsEurope

Virgin plastic is mostly made in North America (18%), Europe (19%) and Asia (50%, with China accounting for 29%).

Breakdown of global plastics production



* Plastic materials: only thermoplastics and polyurethanes
Source: PlasticsEurope Market Research Group (PEMRG) and Conversio Market & Strategy GmbH

CURRENT MANAGEMENT OF PLASTIC WASTE: A COMPLEX MOSAIC

Plastic objects become waste once products are consumed, and waste management is extremely variable from country to country. There are four broad groups of countries:

- developed economies with regulations that encourage recycling, and developed economies that do not have such incentives;
- developing economies with large industrial bases, and developing economies with little industrial activity.

DEVELOPED ECONOMIES: SITUATION HEAVILY DEPENDENT ON LOCAL REGULATIONS

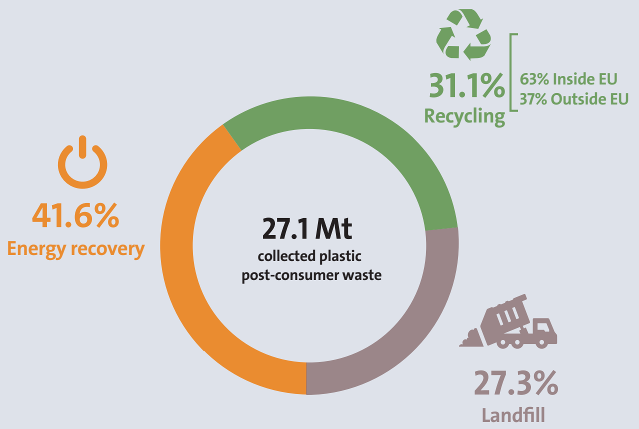
Developed economies with regulations that encourage recycling tend to be mature economies (rich country, modest growth) with good traditional waste management infrastructure (landfill, energy recovery) and relatively high labor costs.

This applies to Western Europe and Japan. Regulations to encourage recycling come in a variety of forms. It is quite common to set up organizations to oversee recycling. These organizations are used to finance some of the costs involved in collecting and sorting plastic waste. Funding generally comes from suppliers – producers and retailers – or is raised from consumers via green levies. This allows externalities relating to end-of-life management to be re-internalized into product pricing.

Recycling in these situations relies on significant infrastructure for sorting and processing plastic waste by polymer type, capable of producing recycled plastic suitable for reuse by manufacturers. These countries also use measures to increase the cost of traditional processing solutions, in the form of taxes on landfill and incineration. Countries in this category can attain recycling rates in the order of 30%.

Developed economies without regulatory incitement possess characteristics similar to the first group, but they focus on traditional waste management methods: landfill and incineration. These countries are typified by the USA and Australia. Recycling remains underdeveloped and marginal in the absence of specific regulations to boost its competitiveness relative to other forms of processing. Less than 10% of plastic waste are recycled locally.

Management of plastic waste in Europe in 2016
(EU28 + Norway and Switzerland)



Source: PlasticsEurope Market Research Group (PEMRG) and Conversio Market & Strategy GmbH

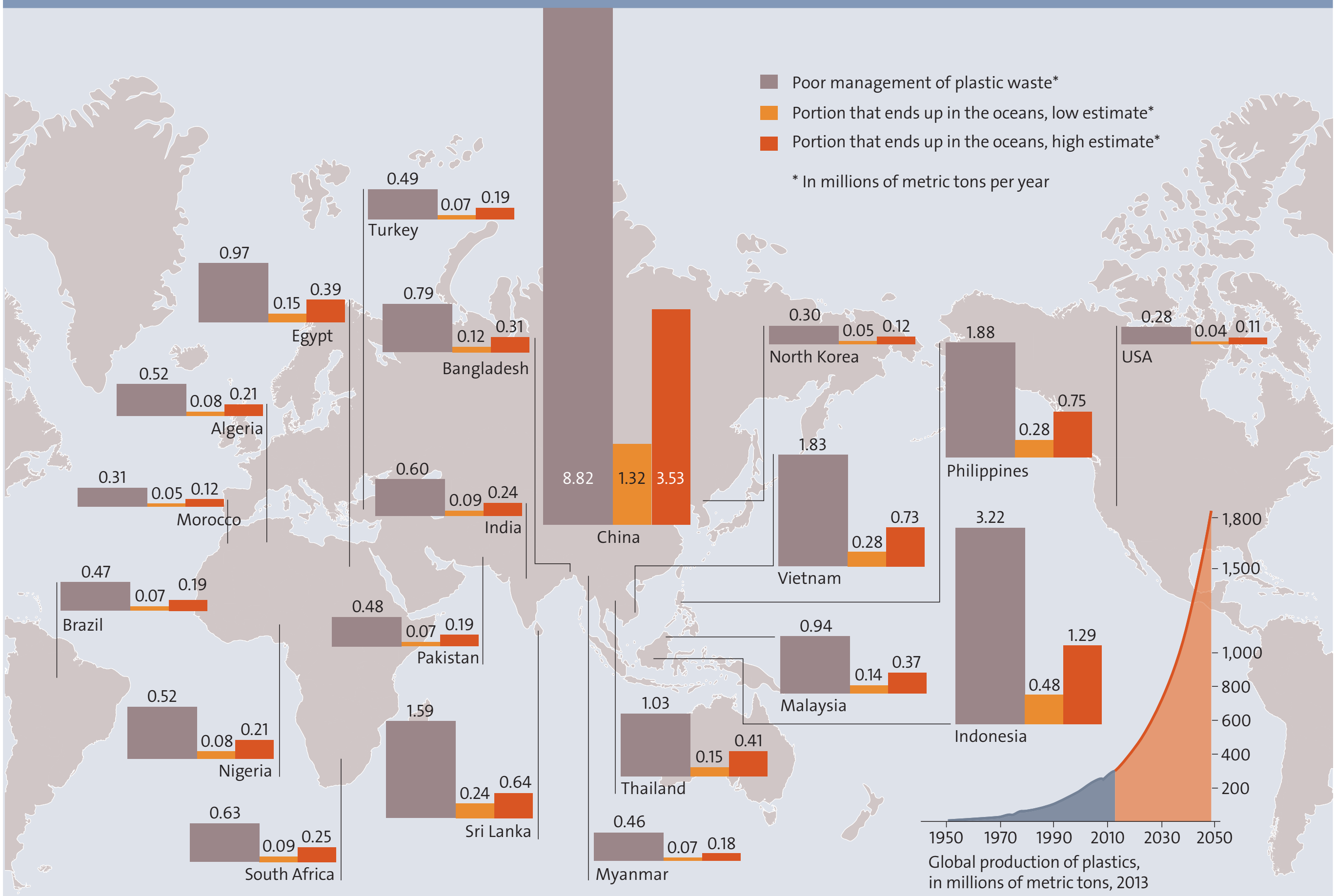
DEVELOPING ECONOMIES: SITUATION DEPENDENT ON LOCAL INDUSTRIAL DEMAND

Industrialized developing economies are generally characterized by inadequate waste management infrastructure. Collection is not systematic and a large portion of household and industrial waste continues to be dumped at numerous unofficial and unregulated sites. Informal networks tend to be well developed and organized. Recycling develops primarily in reaction to the value of waste, driven by local industrial demand.

This is the case in China, India and Brazil. Infrastructure for sorting is underdeveloped and is replaced by informal networks. Processing infrastructure develops as a function of the volumes of material available. Countries in this category can attain recycling rates in the order of 20%.

Developing economies with limited industrialization recycle very little of their plastic, logically enough, as the waste is worth less on the local market. A major portion of waste ends up in the ocean, often swept out to sea via informal dumps and rivers.

Quality of plastics management
20 countries with the worst management of plastic waste



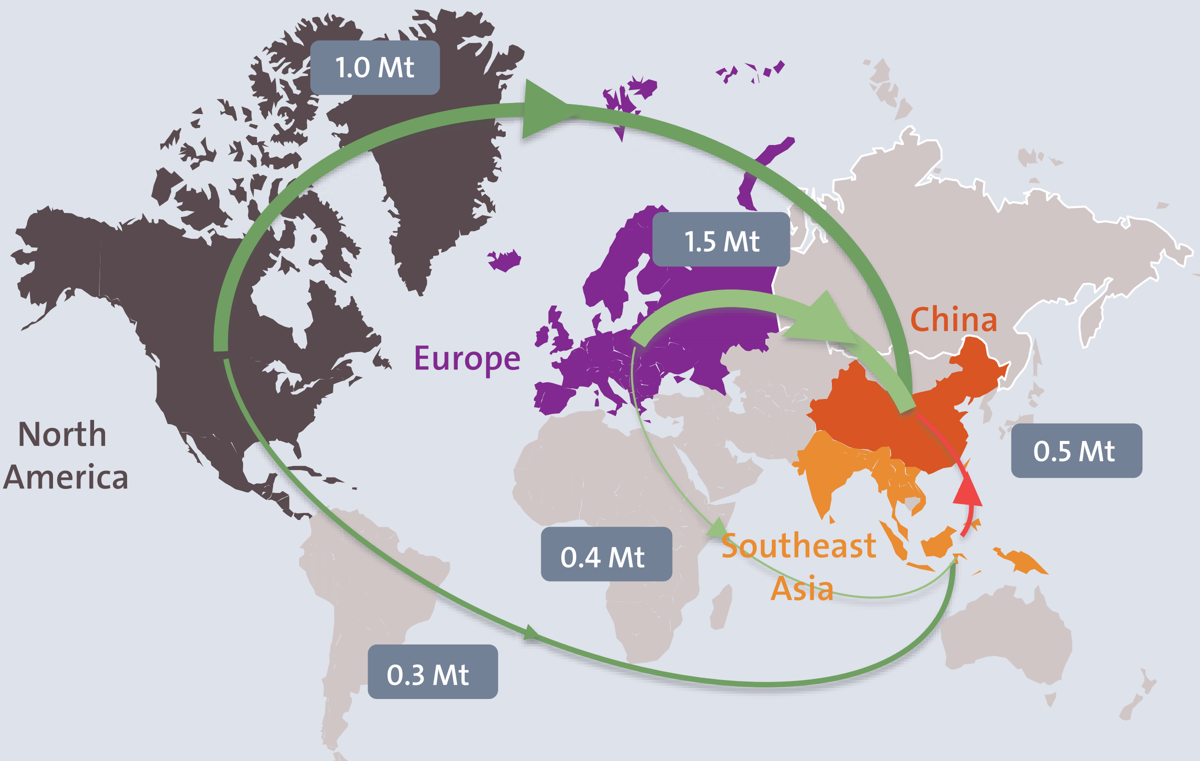
WHERE ARE PLASTICS RECYCLED: LOCAL RECYCLING AND INTERCONTINENTAL FLOWS

Most waste is recycled locally, either in the producer country or a nearby country, but a sizeable export industry has also emerged over the past 30 years. This market essentially involves flows to China, where the material is in high demand, from developed economies (both those with and without regulations to incite recycling). This waste export market takes advantage of low freight rates for return legs on bulk container carriers after they have offloaded cargo from China at ports in Europe and the United States.

In 2017, Europe exported over 2 billion metric tons of plastic waste to China. This market is currently in a transitory period as a result of a Chinese government ban on the import of post-consumer waste that came into force in January 2018. New markets have emerged via Southeast Asia, but it is likely that these countries will also ban imports. These changes represent a major challenge to recyclers as they concern very large volumes. However, the long-term effect of such measures is to encourage local recycling.

Main global plastic waste flows before China's ban

Net exports from Europe and North America to Asia in 2017. These flows were already well down on 2016 and continued to evolve in 2018 following the Chinese government's decision to ban imports of post-consumer plastic waste.



Source: comtrade.un.org/data

WHAT HAPPENS TO RECYCLED PLASTIC?

Recycled resins can deliver attractive technical properties and are suitable substitutes in many applications. There are pretty much as many possible uses for it as there are for raw plastic: bottles, fabrics, packaging, automotive, household appliances, construction, etc. Recycled plastics meet around 10% of global demand for plastic.

Some applications are harder to service, however, for technical or regulatory reasons. For example, food-grade certification requires a feedstock with very high levels of traceability. It is also difficult to substitute 100% recycled resins for certain plastics able to withstand very high pressures. Bear in mind that, historically, users of plastics would buy in recycled plastic because it was cheaper than virgin plastic.

Mechanical sorting centre - plastics
©Veolia photo library - Alexis Duclos

II. WHY AND HOW SHOULD WE ACCELERATE PLASTIC RECYCLING?

ENVIRONMENTAL BENEFITS: REDUCE POLLUTION AND CLIMATE CHANGE

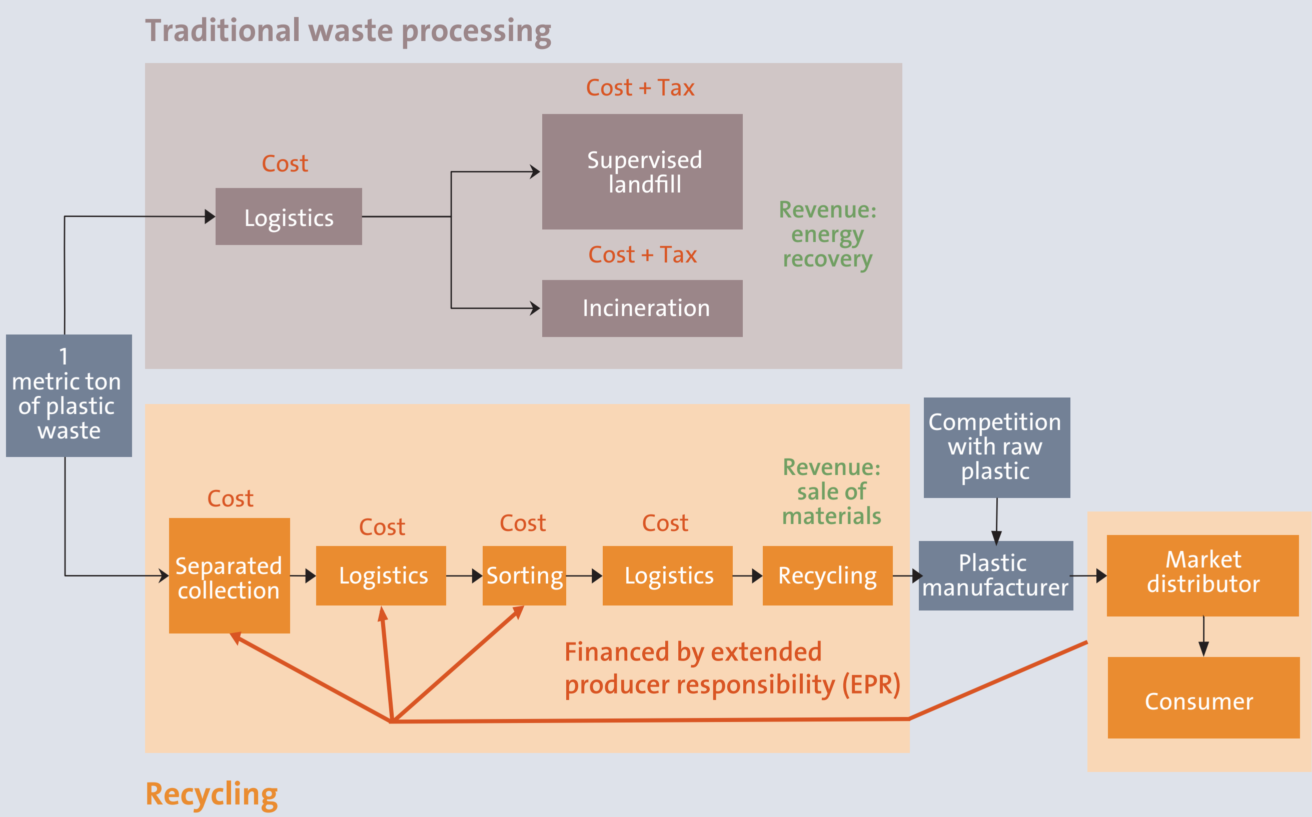
Currently, most plastic waste goes to landfill or is released into the environment one way or another. Every year, in Southeast Asia and China, 4 to 12 million metric tons of plastic packaging is swept down rivers and ends in the oceans. This plastic takes hundreds of years to decompose and constitutes a grave threat to the marine environment.

Recycling plastics also leads to significant reductions in atmospheric emissions of CO_2, because using recycled plastic avoids emission of an amount equivalent to that generated during production of raw plastic (box p. 20).

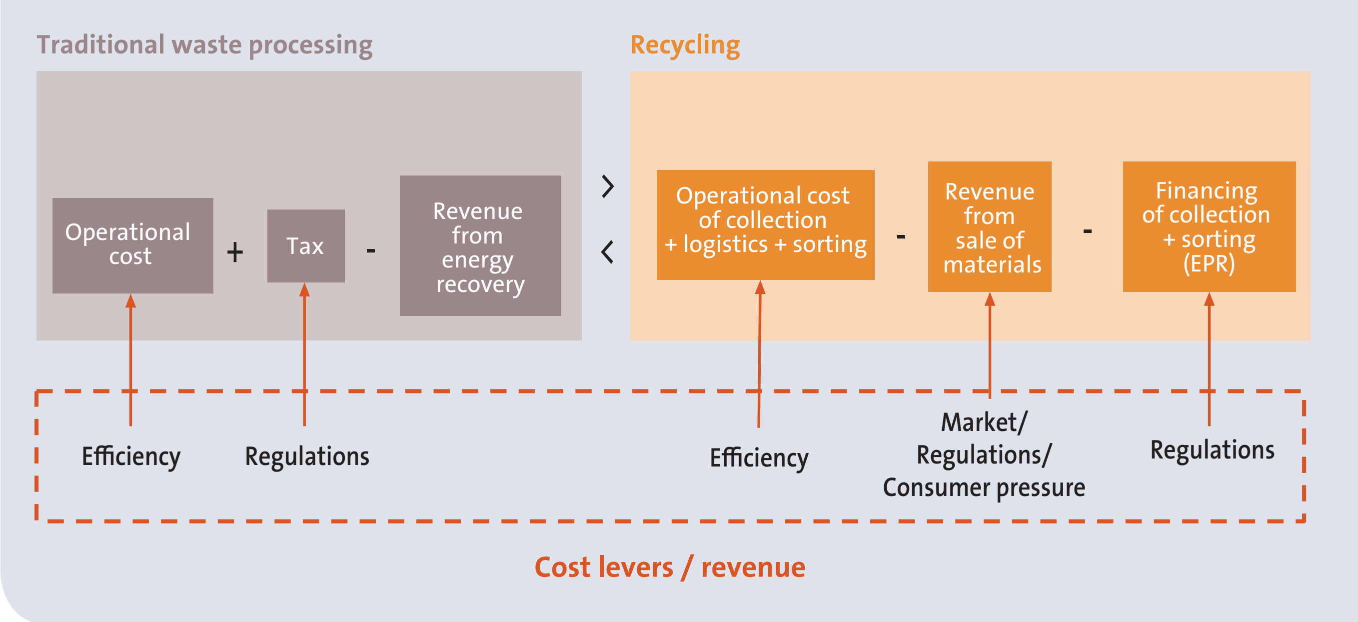
ECONOMIC AND SOCIAL BENEFITS: EMPLOYMENT, VALUE CREATION AND ENERGY SELF-SUFFICIENCY

Developing recycling also fosters local growth by re-internalizing employment within a territory. Typically, a plant producing about 50,000 metric tons of recycled plastic will employ around 30 people. This is significantly

Plastic material flows to different processing methods



Financial equation of different processing methods



more jobs than those generated by sending an equivalent amount of waste to landfill or incinerating it, or by the petrochemical industry synthesizing an equivalent quantity of virgin resins – and these jobs are local.

Setting up a system to recycle plastic waste allows a local industry to emerge and recover value from the recycled material. Where there is no recycling, energy recovery is the only income-generating possibility.

However, because plastic waste recycling systems are logistically more complex than traditional waste processing systems (separate collections, differentiated flows, etc.), this leads to higher waste management costs. This additional cost has to be covered by producers and consumers of plastic goods through extended producer responsibility (EPR).

Developing this activity also helps to deliver resource independence to countries with few oil or gas resources, because making raw plastic requires crude oil or natural gas.

> *There are factors inhibiting development of recycling at every stage of product life cycles: in product design, during waste management procedures, and in the ways that recycled products are used.*

MOBILIZING AND ALIGNING ALL STAKEHOLDERS TO REDESIGN THE PLASTICS ECONOMY

Since recycling is an environmentally and economically virtuous process, what are the factors holding back its expansion?

There are factors inhibiting development of recycling at every stage of product life cycles: in product design, during waste management procedures, and in the ways that recycled products are used.

A sustainable recycling sector can only emerge if the very large numbers of actors in the ecosystem, at every stage of the product life cycle, are aligned, or at least able to exert significant influence. This involves manufacturers that produce plastic products, petrochemical companies that produce raw plastic, retailers, consumers, waste managers, city authorities, governments, regulators and NGOs.

MANUFACTURERS: IMPROVING ECO-DESIGN AND THE USE OF RECYCLED PLASTIC

Products can only be recycled in economically acceptable conditions if recycling is built into their design. For instance, recycling becomes far more complex when dealing with products that use multi-layer plastics, particularly different polymers or materials. Using single-layer plastics facilitates recycling.

Furthermore, certain theoretically recyclable polymers are not recycled in practice because they appear in insufficient quantities in waste streams. This shows how recycling is promoted when manufacturers use polymers that are already in widespread use on the market and for which there are pre-established recycling systems.

It is also at this stage that decisions whether or not to include recycled plastic in a product are taken. Recycled resins are often hampered by problems of odor or color. This means that it is difficult to offer an alternative that is exactly equivalent to raw resins. So, it is important to include these constraints during product development phases run by the operational marketing teams responsible for the life cycles of these products. Similarly, plastic manufacturers required to include recycled resins in products also have to meet the technical challenges involved in increasing the amount of recycled material in the products.

REGULATORS: RESTRICT ALTERNATIVE METHODS FOR MANAGING END-OF-LIFE PLASTICS AND ENCOURAGE DEMAND FOR RECYCLED PLASTIC

Plastic waste can follow several possible processing paths. In the worst case, it will end its life dumped in the wild or floating in the ocean. It can also be dispatched to a regulated landfill site, be incinerated or recycled.

In mature economies, ratcheting up restrictions on options other than recycling has the knock-on effect of boosting recycling. Taxes on landfill, as practiced in France and the UK for example, or outright bans on allowing landfill disposal of certain categories of waste are the most effective ways to limit the amount of plastic waste sent to landfill. The European Union has set a target of only 10% of plastic waste to landfill by 2030, compared to around 30% at present. Taxes on incineration are also being increasingly used to limit this form of waste processing.

But recycling can only develop where appropriate infrastructure and collection rules are in place. Separated collection systems improve efficiency using deposit mechanisms or innovative collection arrangements involving consumers and brands. In October 2018, the European Parliament voted for a 90% collection target for plastic bottles in the EU by 2025.

Just as with the circular economy, the sustainability of recycling is also predicated on industrial demand for recycled material. Historically, it is cost factors that determine if manufacturers buy recycled plastic. This is because it is generally sold for a lower price than the virgin equivalent. Because of the correlation between the price of virgin plastic and that of crude oil, the plastic recycling sector is impacted by variations in the price of Brent crude.

In order to protect the recycling sector from crude oil price volatility, measures could be taken to decouple the market for recycled plastic from the market for raw plastic. A requirement to include recycled plastic in products made from plastic would help to create a discrete market in recycled plastic, one where raw plastic could not be simply used instead. In October 2018 the European Parliament voted to make it mandatory for beverage containers to contain at least 35% recycled plastic by 2025.

RECYCLERS AND WASTE MANAGEMENT PROFESSIONALS: INCREASE EFFICIENCY OF SYSTEMS AND QUALITY OF RECYCLED PLASTIC

Innovations in sorting technologies make it possible to sort materials more efficiently – and open the possibility of processing new flows – with greater yields. Some of the latest sorting robots use artificial intelligence to improve their ability to recognize waste. The sector can also benefit from the scaling effect achieved by concentrating sorting and processing at centralized sites. The resultant marginal decrease in production costs per metric ton of recycled plastic can help to drive the sector. Efficiency gains are possible in collection, sorting and processing.

CONSUMERS AND CITIZENS: GREATER COLLECTIVE AWARENESS AND BETTER SORTING

Changes in final consumers' demands and behaviors can also lead manufacturers to include more recycled plastic in their products. This is a phenomenon seen in the food industry, which is very much in the firing line in terms of plastic pollution of the oceans. Pressure from consumers and civil society pushes brands to increase the amount of recycled plastic in their packaging.

Lastly, consumers too have to shoulder some of the responsibility for separated collection by sorting their waste properly. Following sorting guidelines correctly has a direct impact on the quality of streams available for recycling. Improving the sorting of household waste demands clearer information about the guidelines as well as their standardization, which is an issue for public authorities.

From the environmental and socioeconomic standpoints, the best answer to the problem of how to manage waste plastic is to recycle it.

CONCLUSION

From the environmental and socioeconomic standpoints, the best answer to the problem of how to manage waste plastic is to recycle it. A plastic recycling industry already exists, but it needs to consolidate to scale up and increase its efficiency and capacity. Recyclers must work very closely with actors at all stages of the value chain to throw off the technical, psychological and economic shackles hindering greater substitution of recycled plastic for raw plastic. Regulators too need to help create propitious frameworks for this industry to flourish, encouraging eco-design, separated collection and the inclusion of recycled plastic in products. Lastly, consumer pressure on brands is determining, as companies worry about losing significant market share because of actions such as boycotts, for example. Citizen engagement and awareness of environmental problems is sufficient to force manufacturers to act.

PLASTIC RECYCLING AND IMPACT ON CO_2 EMISSIONS

Two forms of waste processing make it possible to stop plastics being released into nature: incineration and recycling. What are the respective environmental impacts of these two methods for managing end-of-life plastics? Shown below are estimates of these impacts, made by comparing net greenhouse gas emissions (GHG) for each method. The waste management process that emits the least, assuming that variables are comparable, is judged the most environmentally friendly. Net GHG emissions for a process are expressed as follows:

> Net GHG emissions (metric tons of CO_2e/ metric tons of plastic) =
> Actual GHG emissions (1) - Credits (2)

CO_2e = CO_2 equivalent

(1) **Actual** emissions are the sum of direct emissions relating to transportation and energy use during processing, and processing rejects in the case of recycling. Actual emissions vary according to the type of polymer processed, the distance raw materials are transported, the quantity of energy used, the local energy mix and energy efficiency. For example, it takes more energy to recycle PET than to recycle PE/PP.

(2) **Credits** are GHG emissions avoided thanks to recycling, for example by avoiding emissions linked to the production of new products made from raw plastic, or thanks to incineration, producing energy that is not generated from the carbon-sourced energy mix. These credits vary as a function of the polymer, the local energy mix and the cogeneration performance of the incinerators.

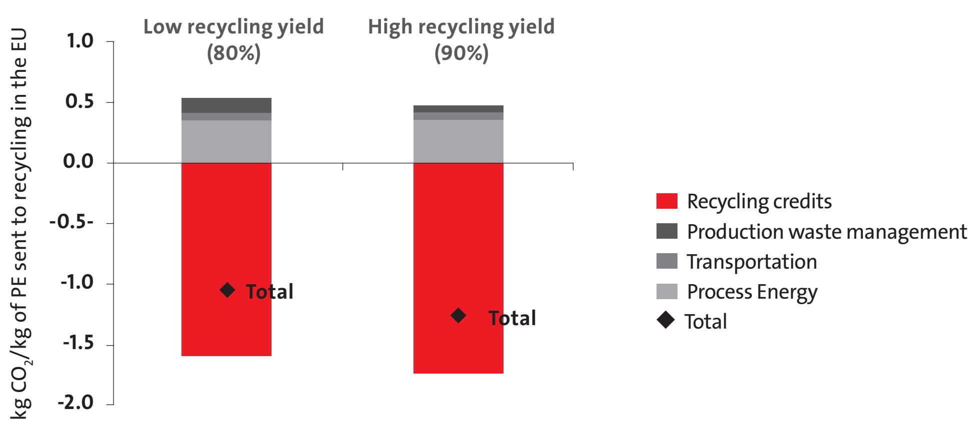
EXAMPLE:
NET EMISSIONS RELATING TO RECYCLING POLYETHYLENE IN THE EU

(1) Actual GHG emissions are shown in gray and are equivalent to approx. 0.5 kg CO_2e/kg PE.

(2) GHG emissions avoided thanks to recycling are shown in red and are equivalent to approx. 1.5-1.8 kg CO_2e/kg PE.
Net emissions are the difference between the two, a net saving from recycling of 1-1.3 kg CO_2e/kg.

Similarly, a calculation is made to determine net emissions from incinerating PE using current technologies: the energy recovery benefits (-2 kg CO_2e/kg) do not sufficiently outweigh the environmental impact (3 kg CO_2e/kg), i.e., surplus emissions of 1 kg CO_2e/kg.

This shows that recycling PE in the EU is not the most environmentally friendly option.

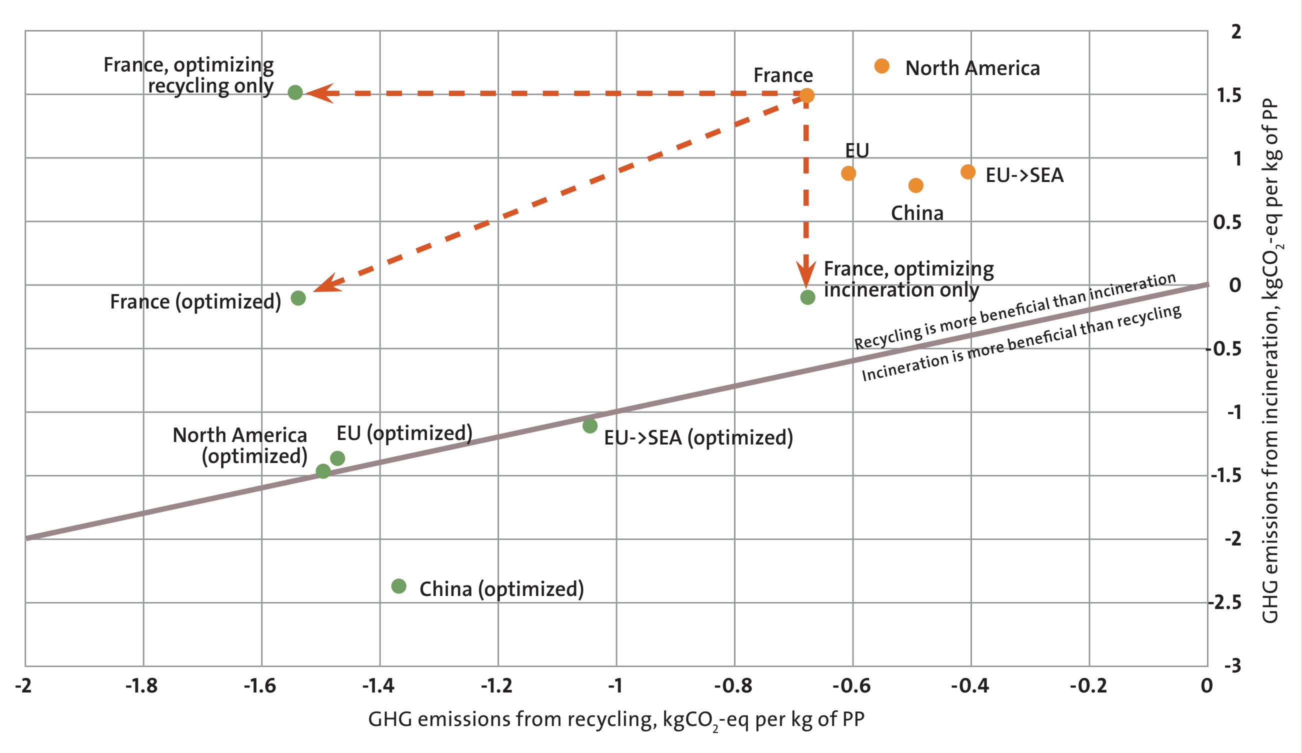


Life cycle analysis demonstrates that **recycling is always the most environmentally friendly option with current processing technologies**, whether processing PP/PE or PET, in France or Asia, irrespective of whether the energy performance is low or high (assuming use of current incineration facilities). The same analysis shows that using recycled plastic in place of raw plastic can cut GHG emissions by 20–50%.

However, if we look at a theoretical "optimal" case where incinerators become more efficient in terms of energy recovery (heat and electricity), then incineration can deliver fewer negative environmental impacts than recycling in regions with a very high-carbon energy mix:

- optimized incineration of HDPE would be the preferred solution in China, the USA and Europe, except in France, as the French energy mix is overwhelmingly nuclear;
- in China, optimized incineration of PP would emit less GHG than recycling, but the two solutions would be equivalent in the rest of the world;
- however, recycling is the best solution everywhere for PET, even assuming the optimized incineration scenario (except in China, which has a very high-carbon energy mix).

EXAMPLE:
RECYCLING OR INCINERATING PP: COMPARING NET EMISSIONS



In the short term, optimized incineration of plastics could be an interesting solution in countries without a well-embedded waste management culture and that remain heavily dependent on high-carbon energy sources such as coal.

However, the comparative theoretical benefits of incineration are sure to disappear over the medium term with the rise of renewables in the overall energy mix. Recycling will therefore remain the most climate-friendly solution.

WHY THE "NEW PLASTICS ECONOMY" MUST BE A CIRCULAR ECONOMY

Daniel Calleja
Director General of the Directorate General for Environment, European Commission

Daniel Calleja has been Director General of the European Commission's Directorate General for Environment since September 2015, before which he was Director General of DG GROW (Internal market, industry, entrepreneurship and SMEs).

From 1993 to 2004, Mr. Calleja worked in the cabinets of several Commissioners, including the President of the European Commission, advising on Transport and Competition matters, State Aids and the application of Community Law. Between 1999 and 2004 he was Head of Cabinet for both Commissioner Oreja and Vice-president Mrs. Loyola de Palacio, in charge of Transport and Energy.

He started his career in the Commission as Member of the Legal Service between 1986 and 1993. During that period, he represented the institution in numerous cases before the European Court of Justice.

KEYWORDS

- CIRCULAR ECONOMY
- WASTE
- SINGLE-USE PLASTIC
- RECYCLING

Every year Europe produces about 58 million tonnes of plastic, and we generate 25 million tonnes of plastic waste. Only 30% of this is collected for recycling, with 39% incinerated and 31% ending up in landfills. The problem lies not only in the amounts of plastic recycled, but also in the quality of the recycling and the resulting secondary plastic. In economic terms, 95% of the value of plastic packaging – worth some 105 billion euros – is lost to the economy every year.

The Plastics Strategy adopted by the European Commission in January 2018 set out how to get the economics right, presenting a vision for a smart, innovative and sustainable plastics industry. It argued that what is needed is a "New Plastics Economy" which must be a circular economy which eliminates waste, maximises value, and uses plastic efficiently. In doing so it will help protect our environment, reduce marine litter, greenhouse gas emissions and our dependence on imported fossil fuels.

Plastic is here today and it is here to stay. The Plastic Strategy clearly emphasizes the value of plastic in our households and in our economies; indeed it is at pains not to demonise the material, whilst drawing attention to the damage caused by our failure to manage it properly.

INTRODUCTION

The European Union Circular Economy Action Plan[1], adopted in 2015, builds on several decades of European environmental legislation, and on a recognition that where Member States had been successful in meeting waste targets it was usually because they got the economics right. They had put in place the separate collection and landfill charging systems that made it viable to invest in recycling capacity. They had arrived at the point where waste was regarded as valuable, because it was collected and sorted.

The Plastics Strategy adopted by the European Commission in January 2018 is an integral component of the Circular Economy Action Plan, and put this material firmly in the circular logic. Building on the new legal obligation[2] to achieve 55% plastics packaging recycling by 2030, and targets to recycle at least 65% of municipal waste and landfill less than 10% by 2035, the plastics strategy set out how to get the economics right, presenting a vision for a smart, innovative and sustainable plastics industry. It argued that what is needed is a "New Plastics Economy",

1 http://ec.europa.eu/environment/circular-economy/index_en.htm
2 in the revised Packaging and Packaging Waste Directive

addressing all parts of the circle, from extraction to design and production, from use to re-use, from disposal to recycling and return to the economy as secondary raw materials. It also meant dealing with the plastic that escapes from proper circular management into our environment, particularly the marine environment.

THE NEW PLASTICS ECONOMY

The need for an economic approach is clear when you consider the economic importance of plastic, its relative cheapness, and its diverse externalities. Every year, Europe produces about 58 million tonnes of plastic, and we generate 25 million tonnes of plastic waste. Only 30% of this is collected for recycling, with 39% incinerated and 31% ending up in landfills. The problem lies not only in the amounts of plastic recycled, but also in the quality of the recycling and the resulting secondary plastic. In economic terms, 95% of the value of plastic packaging – worth some 105 billion euros – is lost to the economy every year. This is quite literally a wasted opportunity, and it is why the first axis of the Plastics Strategy is "improving the economics and quality of plastic recycling".

A "New Plastics Economy" is needed, addressing all parts of the circle, from extraction to design and production, from use to re-use, from disposal to recycling and return to the economy as secondary raw materials

Improving the purity of waste streams and the quality of recyclates means going right back to the beginning of the circle: to the design and production of plastic products. This is even more important with plastic than most other materials, as its adaptability is based on a wide variety of polymers and additives that can make recycling particularly complex and challenging. That is why the Plastics Strategy set the strategic aim that by 2030 all plastics packaging will be reusable or recyclable. The legal framework will help here, with the on-going review of the "Essential Requirements" in the Packaging and Packaging Waste Directive giving the opportunity to set minimum basic rules for all packaging put on the EU market. Similarly the new obligation for all packaging to be subject to Extended Producer Responsibility (EPR) schemes by 2024 will incentivise better packaging design. Eco-modulation in EPR schemes has been demonstrated as particularly effective in internalising externalities of difficult-to-recycle substances and composites, ensuring that life-cycle impacts are also integrated into design decisions in a rational and proportionate way – and also in a more flexible way than by decree of legislators. The importance of this interplay between the material composition of a product, its functionality and its treatment at the end of its useful life has been more generally recognised by the Commission. Work is ongoing on the development of a European approach to address the "interface between chemical, product and waste legislation"[3] which will look at the options, both legal and economic, to dealing with pertinent issues for plastic, such as "legacy" substances and the balance between safety, hygiene and recyclability.

Everybody understands the importance of the balance between supply and demand in making markets work. On the supply side, new separate collection obligations and recycling targets will ensure a plentiful supply of plastics for recycling in Europe, particularly in the wake of the Chinese restrictions on imports of waste. But what about the demand side? Without a clear and dependable demand for recycled plastics, there will not be the necessary confidence to invest in recycling facilities. We estimated that in order to meet our objective of quadrupling plastics recycling capacity in Europe from 2015 to 2030, investments of between €8.4 and 16.6 billion will be needed. Yet today only about 6% of the plastic in new products comes from recyclates, and this is often limited to low-value or niche applications. We have called on the private sector to rise to this challenge by pledging, before 30th September 2018, to boost their uptake of recycled plastics in their products to a collective total of at least 10 million tonnes per year by 2025. We have received some good individual pledges and we are now assessing whether the pledgers will together reach the target we set, or whether we will have to go beyond such voluntary approaches to consider further, and perhaps regulatory, action.

Making sure that the recycling streams going to those facilities are clean enough to make recycling viable requires effective separate collection. Even if technology is being developed for faster and better sorting of waste at facilities, separate collection has generally proven to be more cost-effective, and an important precondition to viable recycling. As we move forwards, a combination of eliminating the worst substances from plastic products, of disincentivizing the bad ones through eco-modulation of EPR fees, of improved separate collection, and of optical and laser sorting, will drive the move to cleaner plastic waste streams. Combined with the roll out of better technology for chemical recycling, we will see greater confidence in the quality of recyclates and their increasing use.

The Plastics Strategy includes a specific axis concerning the investments and innovation that are fundamental to make plastics more sustainable. Getting the economics right means increasing private investors' confidence, but also tackling market failures through strategic use of public investment, particularly in research and innovation. The creation of a Strategic Research and Innovation Agenda for plastics in 2018 promotes funding of research and

3 See Communication adopted with the Plastics Strategy on 16th January 2018, COM(2018) 32 final

innovation in recycling, removal of hazardous substances and microplastics, and the development of feedstock alternatives. The Strategy also announced increased research investment from the EU Research and Innovation Programme Horizon 2020, with an additional 100 million euros. This will come on top of more than 250 million euros already invested so far. To raise awareness about these and other financing opportunities, and to improve the bankability of projects, the Commission has established in cooperation with the European Investment Bank, the Circular Economy Finance Support Platform.

The Strategy also set out to address the environmental and possible health risks of microplastics that pollute our soil and waters, and perhaps also the food chain and the air we breathe. The Commission has started work to restrict those microplastics intentionally added to products (such as in cosmetics, paints or detergents) by requesting the European Chemicals Agency to review the scientific basis for considering a restriction under REACH, based on a recently completed study.

For microplastics resulting from the use of products (such as tyres or textiles) or from primary plastic production (for example from spills of pre-production plastic pellets), we envisage focussed actions linked to standardisation, labelling, possible regulatory measures, as well as increased capture through wastewater treatment.

We will also tackle the so-called oxo-degradable plastics which do not biodegrade in open environment but rather fragment in tiny pieces exacerbating the microplastics accumulation in soils and water.

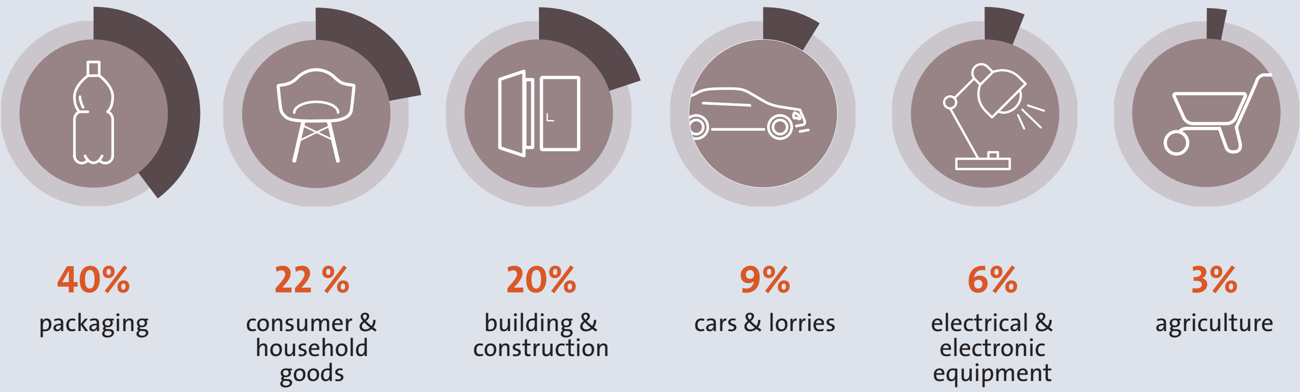
Reactions to the strategy, including an own-initiative report from the European Parliament[4], have been very positive. In the many debates and discussions that I have taken part in since adoption of the Strategy, I have heard the views of many stakeholders active at different parts of the plastic loop. All explicitly support the general objectives and circular approach of the New Plastics Economy. Then I usually hear that the real problem in achieving the vision is at another part of the circle: recyclers could recycle more and better if only product design were better, or separate collection were improved; producers could include more secondary plastic in their products if only the quality and supply were guaranteed; the waste management sector would be prepared to make the necessary investments if only there were legislative measures ensuring a significant uptake of plastic recyclates. These arguments are legitimate, but they serve to convince me that the circular approach is the right one because it is integrated and systemic. It recognises that the many loops that would make up a new plastics economy depend in turn on the many public and private players talking to each other and to find systemic solutions.

4 Report of MEP Mark Demesmaeker, adopted on 13th September 2018 http://www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P8-TA-2018-0352

Europe produces a huge amount of plastic

58 MILLION TONNES

EVERY YEAR



Source: PlasticsEurope

It is reassuring to see just how consistent circular economy approaches are with our existing legislation on waste. The long-established waste hierarchy, enshrined in the waste directives, puts waste prevention at its pinnacle, and moving up the hierarchy of waste management options implies working throughout the production and consumption cycle. So in delivering circular approaches, including for plastics, it is important that the lawyers understand the economics and that the economists understand the law.

PLASTIC WASTE IN THE WRONG PLACE

We also have to deal with some waste that doesn't even make it onto the bottom of that hierarchy. It is said that litter is "waste in the wrong place", and when it comes to plastic there cannot be a worst place than in the marine environment. Single-use plastic products can easily be criticised from the perspective of circularity; their functionality and value to the economy are very limited in time, and when they are littered their value is totally lost. But what inflamed public opinion against plastic litter was not so much these wasteful consumption habits in themselves as the realisation of the longer term effects on marine life.

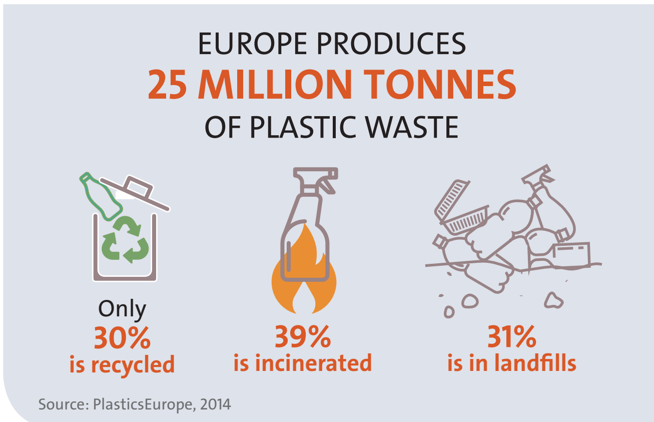
Every year, between 150 000 and 500 000 tonnes of plastic waste originating in the EU ends up in the oceans. Once littered, it remains in the environment for centuries. It has been widely repeated that globally, if we continue this way, there will be more plastic than fish in the ocean by 2050. But although public and political discourse has focused on the impact on marine life, in order to deal with these catastrophic effects, we have to address the wasteful consumption habits.

In the Plastics Strategy, we announced legislative action to tackle plastic marine pollution. And a draft Directive "on the reduction of the impact of certain plastic products on the environment"[5] was tabled by the Commission already in May of this year. Despite this tight time limit, and despite the many emotions raised by marine pollution, the proposal is a well-balanced, evidence-based, targeted and proportionate. It is based on the best data and analysis we have, a comprehensive impact assessment and full stakeholder consultation. It targets the main items responsible for the problem in a proportionate way, and it tackles each according to the particular pathways that they arrive in the marine environment.

We know from 276 beach counts across the EU (the best indicator we have for marine litter) that single use plastic items constitute about 50% of such litter, while fishing gear represents a further 27%. For Single Use Plastics, the Commission proposal focused on the 10 most found single use items. Together these constitute 70% of all marine litter items. The rules we set out in our legislative proposal are proportionate and tailored to get the best results. This means different measures will be applied to different products. Together, the new rules will put Europe ahead of the curve on an issue with global implications. Concretely, the new rules will introduce:

- **A plastic ban for certain products:** Where alternatives are readily available and affordable, single-use plastic products will be banned from the market. The ban will apply to plastic cotton buds, cutlery, plates, straws, drink stirrers and sticks for balloons which will all have to be made exclusively from more sustainable materials instead. Single-use drinks containers made with plastic will only be allowed on the market if their caps and lids remain attached;
- **Consumption reduction targets:** Member States will have to reduce the use of plastic food containers and drinks cups. They can do so by setting national reduction targets, making alternative products available at the point of sale, or ensuring that single-use plastic products cannot be provided free of charge;

5 COM(2018) 340 final of 28.05.18 http://ec.europa.eu/environment/circular-economy/pdf/single-use_plastics_proposal.pdf



- **Obligations for producers:** Producers will help cover the costs of waste management and cleaning-up, as well as awareness-raising measures for food containers, packets and wrappers (such as for crisps and sweets), drinks containers and cups, tobacco products with filters (such as cigarette butts), wet wipes, balloons, and lightweight plastic bags. Industry will also be given incentives to develop less polluting alternatives for these products;
- **Collection targets:** Member States will be obliged to collect 90% of single-use plastic drinks bottles by 2025, for example through deposit refund schemes;
- **Labelling Requirements:** Certain products will require a clear and standardised labelling which indicates how waste should be disposed, the negative environmental impact of the product, and the presence of plastics in the products. This will apply to sanitary towels, wet wipes and balloons;
- **Awareness-raising measures:** Member States will be obliged to raise consumers' awareness about the negative impact of littering of single-use plastics and fishing gear as well as about the available reuse systems and waste management options for all these products.

For fishing gear, the Commission aims to complete the existing policy framework with producer responsibility schemes for fishing gear containing plastic. Producers of plastic fishing gear will be required to cover the costs of waste collection from port reception facilities, and its transport and treatment. They will also cover the costs of awareness-raising measures.

Through these actions the proposal deals with almost 90% of all single use plastic items found on Europe's beaches. According to our calculations its implementation would reduce by more than half the littering in our seas of these ten single use plastics, it would avoid the emission of 3.4 million tonnes of CO_2 equivalent and avoid environmental damage with a benefit equivalent to €23 billion in 2030. It would result in savings for consumers of around €6.5 billion and the creation of around 30 000 jobs.

These figures are impressive. Some have sought to sow doubt about the accuracy and validity of data or the calculation methods used in our impact assessment, but these were based on the best available data and on disinterested expert analysis. Challenges have (not surprisingly) been levelled at findings that are inconvenient for those that have particular interests. But even if the impact assessment exercise requires some choices and assumptions, it is important to understand that it is subject to the Commission's rigorous and transparent Better Regulation process, and that it is built on objective analysis of evidence, not emotion or interest.

10 most common plastic objects found on European beaches

Source: Based on JRC report

The evidence base has the important effect of targeting our efforts to ensure the maximum benefits from our actions. Such targeting also limits the costs. Of course there will be costs, but business compliance costs such as the commercial washing of multi-use items and refill schemes (estimated at around €2.4 billion) and waste management costs (estimated to increase by €0.8 billion) remain in a different order of magnitude compared to the far more substantial benefits.

The Commission's proposals are now being negotiated by the European Parliament and the Member States in the Council and we await the results of this democratic legislative process. Yet already we see further evidence that we got the balance right, with a high degree of consensus on both the level or our ambition and the approach taken. To our evidence-based proposal we see the co-legislators adding political judgement and taking account of citizens' concerns. The case for action has been found compelling.

THE GLOBAL RACE TO THE TOP...

Worldwide, this proposal is the most comprehensive legal instrument to date addressing marine litter. The EU is once again showing its leadership in the environmental area, but we are also working with global partners to tackle what is a global issue. Studies showing that between 88 and 95% of marine pollution comes from 10 rivers – eight of which are in Asia and two in Africa[6] – are not reason for inaction in Europe. They are reason for Europe to act in parallel and in conjunction with our global partners, who are themselves already taking action. That is why in September 2018, at an event during the 73rd UN General Assembly, the European Commission's First Vice President launched along with the United Nations Environment Programme the challenge of a "global race to the top" in tackling plastic marine pollution.

Studies have shown that the plastic on Europe's beaches and in our seas originates overwhelmingly in Europe, and our substantial plastic waste exports to Asia suggest that much of that which is found in other seas of the globe may also originate in Europe. The most effective solutions in Asia and Africa, where waste management is less developed, will differ from those in Europe. But Europe must not be complacent; we need to clean our own house before asking the same to our neighbours.

... STARTS ON OUR DOORSTEP

Going from the global level, literally to our own house, the European Commission has itself a duty to set a good example, even if the impacts of such individual initiatives seem just a "drop in the ocean". At the "Our Oceans" Conference in 2017, the Commission pledged to phase out single use plastic cups first in its vending machines serving hot drinks, then in all catering activities. This should result in saving 9 million cups per year, equivalent to 25 tonnes or roughly 1kg per staff member: so still quite a big "drop". This is in addition to many other initiatives implemented already by the Commission in the context of the Eco Management and Audit Scheme (EMAS).

SO WHAT ABOUT THE FUTURE?

Plastic is here today and it is here to stay. The Plastic Strategy clearly emphasizes the value of plastic in our households and in our economies; indeed it is at pains not to demonise the material, whilst drawing attention to the damage caused by our failure to manage it properly.

Circular economy approaches are about retaining the value of materials in the economy, which is why they are so pertinent to plastic. Plastic is the only material – so far – specifically addressed in the context of the EU's circular economy approach. This treatment is justified because of its ubiquity, its unique characteristics and the urgent need for an approach that integrates all parts of its life cycle. The "New Plastics Economy" must be a circular economy which eliminates waste, maximises value, and uses plastic efficiently. In doing so it will help protect our environment, reduce marine litter, greenhouse gas emissions and our dependence on imported fossil fuels.

EDITOR'S NOTE:

The European institutions reached, in December 2018, an agreement on the "Single Use Plastics directive" proposed in May 2018 by the Commission. The final text will include: a separate collection target for plastic bottles of 77% by 2025 and 90% by 2029; a mandatory recycled content of 25% for PET bottles from 2025 onwards, 30% recycled content for all plastic bottles in 2030, calculated on average per country. This measure was added during the legislative process in order to increase the demand side of plastics recycling markets. Formal adoption by the European legislators and publication in the Official Journal should take place before the end of the mandate mid 2019. The text will then have to be transposed into national law within two years.

6 https://pubs.acs.org/doi/abs/10.1021/acs.est.7b02368

THE INFORMAL WASTE SECTOR: A SOLUTION TO THE RECYCLING PROBLEM IN DEVELOPING COUNTRIES

Siddharth Hande
Founder and CEO, Kabadiwalla Connect

Siddharth Hande is the Founder and CEO of Kabadiwalla Connect, a technology-based social enterprise located in Chennai. Siddharth is a spatial data analyst by training, interested in social entrepreneurship, technology, urban planning, informality and the circular economy in the developing world.

Prior to Kabadiwalla Connect, he worked as a consultant for some of India's premier urban policy and research think tanks, including the Indo-German Centre for Sustainability at IIT-Madras, The Indian Institute for Human Settlements and the Institute for Financial Management and Research.

KEYWORDS

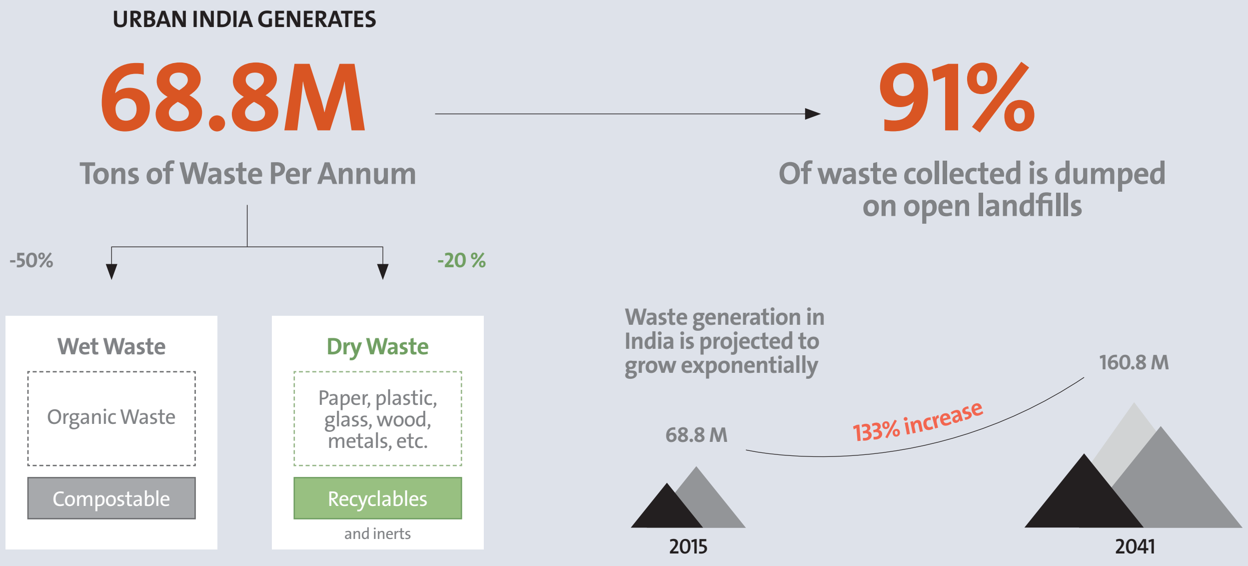
- INFORMAL SECTOR
- REVERSE LOGISTICS SUPPLY CHAIN
- WASTE PICKERS

The recovery of post-consumer waste in cities in the developing world is driven by the informal ecosystem. Kabadiwalla Connect, a technology-based social enterprise based in Chennai, has determined that leveraging the informal ecosystem of urban waste recyclers has the potential to decrease the amount of waste sent to landfills in Indian cities by 70 percent.

In the current scenario, municipalities, multinational brands, and waste management companies struggle to work effectively with informal stakeholders – despite increasing evidence of the commercial, environmental, and social benefits of forming mutually beneficial partnerships. Through a unique business process and award winning technology, Kabadiwalla Connect integrates the informal ecosystem into the reverse-logistics supply chain, helping municipalities, brands, and waste management companies recover post-consumer waste efficiently and more inclusively in the developing world.

Rather than approaching the informality as a problem and developing a new system for waste management, Kabadiwalla Connect uses its technology platform to leverage the already existing informal infrastructure toward a more efficient waste management system. The KC platform makes the informal ecosystem more accessible to other players. Municipalities can utilise informal infrastructure to bring down operational costs; waste management firms can source from it; corporations can carry out their extended producer responsibility through it; apartments and small businesses can send their recyclable waste directly to informal stakeholders that are a part of the informal ecosystem.

Municipal Solid Waste is currently improperly managed in urban India



Source: Department of Industrial Policy and Promotion, 2011
http://www.seas.columbia.edu/earth/wtert/sofos/Sustainable%20Solid%20Waste%20Management%20in%20India_Final.pdf

How did you start working with the informal waste management ecosystem in India?

While reading about the informality in waste management when I was in the development sector, I realized that studies focused mainly on understanding wastepickers, and that there was very little study of the other actors in the informal supply-chain. Due to this, recommendations on waste management solutions for the developing world were largely based on western models – at most with the recommendation of wastepicker inclusion as a footnote.

I was very interested in understanding the entire informal waste management ecosystem: Who do wastepickers sell to? What type of material and how much of it can be currently procured in the informal supply-chain? What are the storage practices and prices as material moves up the supply-chain? How does waste find its way from the wastepicker to the final processor?

In 2015, thanks to an initial grant from the World Economic Forum, Kabadiwalla Connect started mapping and enumerating small scrap-shops (called kabadiwallas in India) that wastepickers sold to, as well as larger informal traders and middle-men in Chennai. The results were quite fascinating:

- Kabadiwallas were ubiquitous throughout the city. There were close to 2,000 in Chennai.

Trash accumulation in Chennai

- They sourced more than 24 percent of the total recyclable waste in Chennai, which includes paper, plastic, glass and metal.
- They were making between 20,000 and 30,000 rupees a month (equivalent to a taxi driver), and had been in the business for quite a long time (13 years on average).
- 52 percent of kabadiwallas owned and operated a smartphone.
- They were hindered by a lack of visibility, lack of formal integration and information asymmetry.

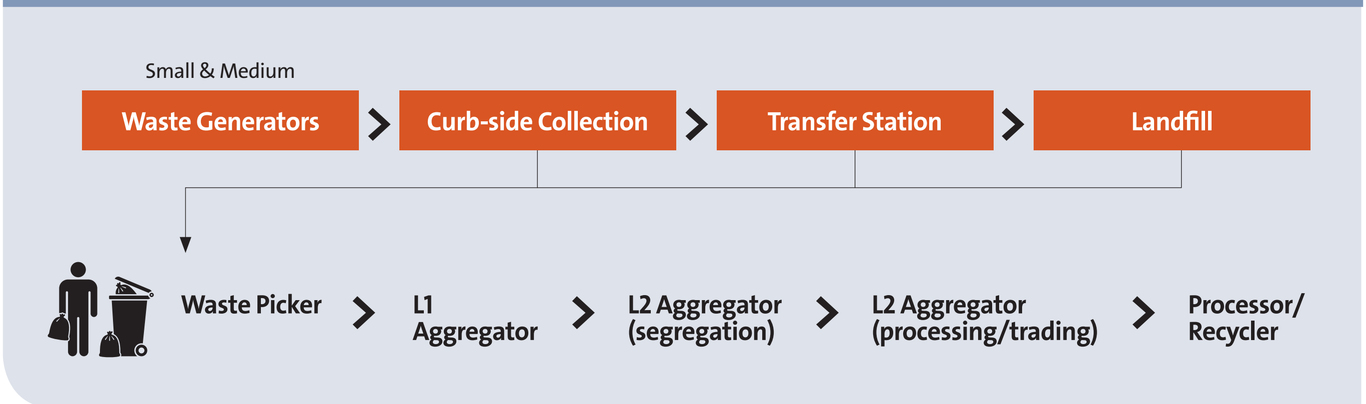
Based on this study, we realized that there was a business case here. We looked specifically at plastics and realized that there was a big disconnect between the volumes available for recycling and what the kabadiwallas were doing. PET seemed to be the most standardized material for recycling but for other types of plastics we were getting mixed signals. We realized that there was a business opportunity in the interface between the informal scrap shops and the formal processing of plastics. We set up a small material recycling facility to procure PET from the informal ecosystem. The main objective was to prove that it was possible to procure consistent volumes from the informal sector and provide certain benefits (better price, better pick up time, clearer signal on the market dynamic of plastics recycling). That is why we have developed a technology-based process that allows us to track the quality and volume of material that we are getting from the informal sector.

After that, based on our initial research, we won another grant from the Global Partnership For Sustainable Development Data, a global network bringing together governments, the private sector, and civil society organizations dedicated to using the data revolution to achieve the Sustainable Development Goals.

With this grant, we are completing the first census-style data collection of the informal sector in Chennai. We are still crunching the data but we already have a sense of the main findings:

- The informal sector represents an extremely robust and decentralized supply chain with significant volumes, especially when it comes to paper and metal.
- When it comes to plastic, the informal sector understands that there is a market but the maturity is yet to come. Therefore, there is a very interesting opportunity here to organize the ecosystem more systematically.

Informal work dominates the recovery of post-consumer waste produced by small and medium waste generators in developing country cities



How does the informal waste management ecosystem work?

Kabadiwalla Connect defines the informal waste supply chain in three levels:

- Level 0 aggregators: Consist of wastepickers who collect waste material from dustbins or landfills and have no input cost. Sometimes L0 aggregators have a method of transportation like a tricycle (called itinerant buyers), which they use to cover a larger area and collect more waste. At times, L0 aggregators collect directly from the households as well. They have no shop/storage space of their own.
- Level 1 aggregators: Known colloquially as kabadiwallas, they are small scrap aggregators who own a shop where they collect, store and minimally process waste material collected from L0 aggregators, households, apartments and small businesses. They typically like to set up shop where they can be guaranteed a constant supply of post-consumer waste – either in residential areas, near industries, or near a landfill. They are material agnostic, and typically buy all material that they deem sellable downstream. In urban India, kabadiwallas typically buy many types of paper, glass, metal and plastic. They generally sell all the material they collect to an L2 or a larger L1 aggregator in weekly or biweekly cycles.

A worker at Kabadiwalla Connect's facility

The kabadiwallas are key players in the city's informal waste collection

Waste Picker > **L1 Aggregator** > **L2 Aggregator (segregation)** > **L2 Aggregator (processing/trading)** > **Processor/ Recycler**

Our survey of over 1,950 kabadiwallas revealed the following

24% of recyclable waste is already informally sourced back from this network

170K tons of recyclables saved form landfills every year

52% of them have smartphones and 100% have phones

$270 earning per month for more than 80% of recyclers (INR 20,000)

74% can deploy their network to procure from the households

- Level 2 aggregators: they primarily buy material from L1 aggregators and bulk generators of recyclable waste. To be viable, they have to be able to store much larger volumes of recyclables, and so favour setting up shop on the periphery of the city. Greater specialisation with regards to material is typically found at the L2 aggregator level, in terms of segregation and/or processing.

The International Monetary Fund (IMF) has an interesting definition of informality related to three groups :

- The outsiders: they are typically informal stakeholders who will never get into the formal sector as they do very low productivity work. The aim is to deliver more equity to these informal workers. They are a mix of L0 and L1 aggregators.

Level 2 aggregators also play an essential role in the informal recycling value chain

Waste Picker > L1 Aggregator > L2 Aggregator (segregation) > L2 Aggregator (processing/trading) > Processor/ Recycler

Our survey of over 200 L2 aggregators revealed the following

69%	7	69%	$12K	28%	36
of them specialise in a single material (Paper/Plastic/Glass or Metal)	employees working under each aggregator	of them have smartphones. 100% of them have phones	average revenue per month	earn profits of $1,500 or more every month	tons - average storage capacity

- The evaders: they earn reasonable revenues but are outside of the marketplace. They are a mix of L1 and L2 aggregators.
- The avoiders: they earn high revenues and take advantage of the system. They represent L2 aggregators as well as processors.

Kabadiwalla Connect is interested in knowing more about how the supply chain works so that we can deliver more equity. Our know-how makes us relevant in the policy space to discuss the informal sector and how the private sector and the public sector can harness it.

It is interesting to think of improving equity through the concept of a "reverse buying club". Volumes are always key in terms of commanding price. At the moment, only L2 aggregators really understand what price they can make in terms of selling to their clients. They actually extract a lot of value and don't pass this information upstream, to L1 and L0 aggregators. That is something that we can tackle

A worker at Kabadiwalla Connect's facility

Wastepicker or L0 aggregator in Chennai

by providing a better transfer of money upstream. For instance, the producers of PET fibers only buy from large aggregators because they want large volumes. We can work with 20 L1 aggregators and aggregate large volumes and offer a better price to them.

What are the interactions between the formal and the informal waste sectors?

It is an extremely competitive supply chain: there are large tensions between the informal and the formal waste sectors on sourcing high value plastics and pricing.

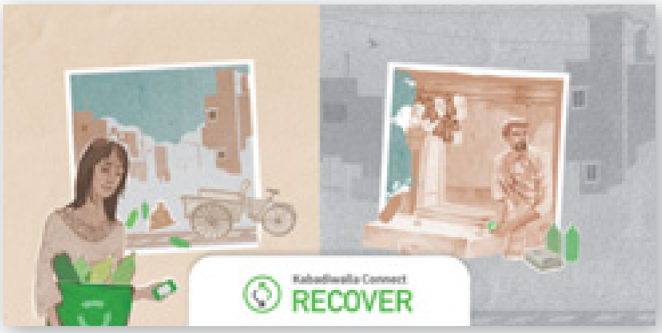
The informal sector, in a decentralized approach, competes very well in this area, despite very poor conditions. Our ambition is to improve these conditions without making them lose their competitive advantage. With L2 aggregators, Kabadiwalla Connect works on formalizing – helping them getting some machines, increasing efficiency, establishing transparent and stable pricing. With L0 and L1 aggregators, we focus more on organizing, as they are not keen on formalizing. For example, in our plastics recovery facility, with the L1, we buy their material, we provide them the right receipts, and we take over their tax burden.

Kabadiwalla Connect's IoT product Urbin in Chennai

How can Kabadiwalla Connect help informal wastepickers solve developing countries' recycling problem?

We like to think about our solution in two parts: what we call KC Recover and KC Transform:

- **KC Recover:** Technology solutions that help clients recover post-consumer waste cost-effectively – by leveraging the informal sector.



Our aim is to integrate the informal sector into a reverse logistics supply chain. We are developing technologies – including IoT products – that help L1 and L2 aggregators work together more efficiently and provide key metrics to increase traceability. For instance, we have developed an IoT bin. When the bin is full, the kabadiwalla is notified and can pick up the trash from the bin. That helps increase the loyalty of L1 aggregators, improves logistics and reduces costs. We also look at the blockchain as a way of guaranteeing the highest standards of transparency on recycling, especially when considering building a Producer Responsibility Organization (PRO) to handle extended producer responsibility.

- **KC Transform:** Solutions that help informal stakeholders create more value from the materials that they source back from the city.

Our objective is to create more value within the informal supply chain. One of the biggest endeavours that we have undertaken is to build a plastic recovery facility that is optimized to procure from the informal sector. We have one and half years of experience with sourcing PET and we have achieved a high quality on average: 80 to 90 % of PET, thanks to a good sorting. With the partnership with Veolia, we are working on improving the high end transformation and valorisation.

What is your business model?

Kabadiwalla Connect helps integrate informal stakeholders into the formal waste collection and recycling supply chain. Through the KC Recover product suite, we can price for traceability, volume discovery and informal sector integration. Our technology guarantees traceability and volume discovery.

With KC Transform, what we are trying to do is to build a franchise model for our plastics recovery facility where we are able to work with other L2 aggregators and help them increase their volumes and improve the standards of their shops.

We are also exploring different options around loyalty: setting up franchises is one of them. We could also build a marketplace around our franchises. We are also thinking of selling some products that are relevant to the informal sector, like this IoT bin that we can sell to a municipality.

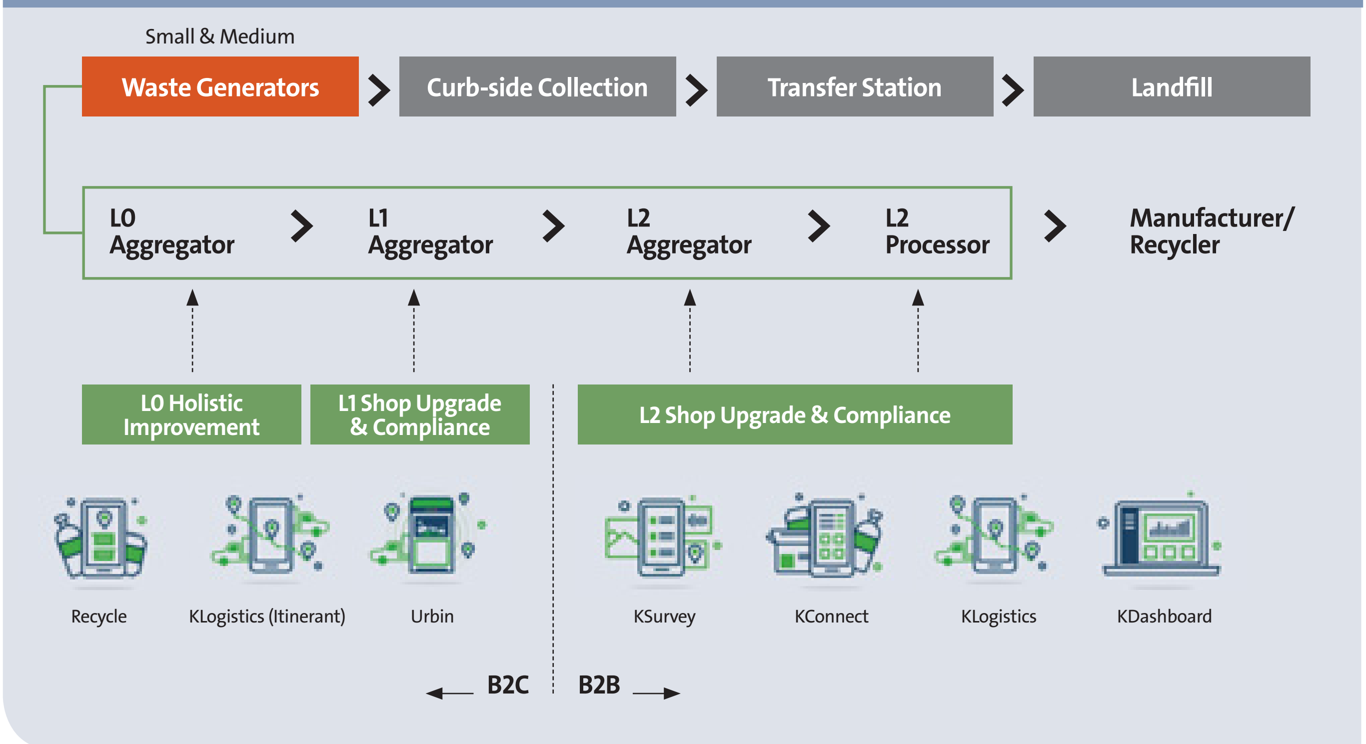
Besides, we also put a social premium on our social impact dimension: improving health and safety standards, upgrading shops, enhancing storage practices, etc.

The KC platform makes the informal ecosystem more accessible to other players. Municipalities can utilise informal infrastructure to bring down operational costs; waste management firms can source from it; corporations can carry out their extended producer responsibility through it; households and small businesses can send their recyclable waste directly to kabadiwallas that are a part of it.

Kabadiwalla Connect's waste recovery facility in Chennai

Ultimately, we hope to use the solutions from KC Recover and KC Transform to develop a Producer Responsibility Organisation (PRO) for cities in the developing world.

Kabadiwalla Connect supports the entire informal recycling value chain



Kabadiwalla or L1 aggregator

Trash accumulation in Chennai

What is the social mission of Kabadiwalla Connect?

Rather than approaching informality as a problem and developing a new system for waste management, Kabadiwalla Connect uses its technology platform to leverage already existing informal infrastructure toward a more efficient waste management system. Our social mission is to make sure that there is no one left behind as interest develops in the idea of a circular economy.

When you think of the kabadiwallas and L2 aggregators, they are entrepreneurial. Our mission is to build the right incentives for this ecosystem because then you are going to see transformation in the lives of L0 aggregators who, at this point, are extremely marginalized. We are trying to develop an ecosystem where L2 aggregators are incentivized to treat L1 aggregators better. For instance, improving their working conditions by providing them gloves.

Rather than approaching the informality as a problem and developing a new system for waste management, Kabadiwalla Connect uses its technology platform to leverage the already existing informal infrastructure toward a more efficient waste management system.

There is a real capital crunch among L1 and L2 aggregators that prevents them from generating higher volumes. We are exploring the possibility of providing them with microfinance support.

How do you leverage return on experience and support replication?

I strongly believe that there is a need for South to South learning. Africa, Asia, and Latin America need to learn from each other, understand their differences, and then mitigate them. South to South learning is going to be critical to support growth in developing countries and we need to organize such a two-way conversation that goes beyond the traditional North-South dialogue.

For instance, from our ongoing field study in Indonesia, we can see that there are ecosystems similar to India. In Indonesia, there are also 3 levels of aggregators but their L1 aggregators are much smaller than in India. It is important that Indonesia and India can learn from each other and increase the replication dynamic. Besides, in the coming years, developed countries might also have to look at the example of the informal waste sector in developing nations as a model for a decentralized and competitive approach.

PLASTICS FROM A WHOLE PLANET PERSPECTIVE

Erin Simon
Director of Sustainability Research and Development, WWF

World Wildlife Fund is an international non-governmental organization that works to stop the degradation of the planet's natural environment and build a future in which people live in harmony with nature.

Erin Simon works to drive positive change across industries by leading WWF's packaging and material science program. As the Director of Sustainability Research and Development, Erin works with companies to improve the sustainability of their supply chains, helping them make informed, responsible decisions for their products and packaging.

KEYWORDS

- BIOPLASTIC FEEDSTOCK
- RECYCLING
- MATERIAL MANAGEMENT
- CIRCULAR ECONOMY

Like all materials, plastic has both drawbacks and advantages[1, 2, 3]. However, most plastic today is made from non-renewable fossil resources and huge volumes of plastic end up as marine litter[4]. Mismanaged plastic also represents a lost opportunity to recover and repurpose valuable material[5]. Connecting product design and waste management innovation will be critical in addressing this global issue. Responsibly sourcing new plastics and cascading value systems where material is used multiple times can help us reduce our demands on the planet[6, 7].

In addressing the global impacts of plastic, the system must be analyzed holistically, and changes will be necessary throughout every step of plastic's lifecycle. World Wildlife Fund (WWF) is a leader of two platforms that strive to address issues associated with material sourcing and waste. WWF works with many diverse partners through the Bioplastic Feedstock Alliance and The Cascading Materials Vision to explore and implement sustainable change and enable a Global Market for Sustainable Materials Management. These initiatives bring together companies, non-governmental organizations, scholars, and policy-makers committed to a future where we source and use plastics more thoughtfully and responsibly.

The Bioplastic Feedstock Alliance (BFA) explores the use and impacts of biobased plastics. WWF has developed a methodology with a clear goal of helping BFA members assess the supply chain risks associated with specific bioplastic feedstocks. The Cascading Materials Vision is a platform that seeks to enable a global system of efficient materials management. This common framework is used to influence relevant sectors toward achievable, sustainable, and inclusive solutions that address the systemic issues that prevent creation, trade, and use of secondary materials (materials which have already been used at least once). BFA and The Cascading Material Vision both fit within the framework of a circular economy.

INTRODUCTION

The majority of plastics used today are made from non-renewable fossil resources. Mismanaged plastic ends up in ecosystems, causing unnecessary stress to the environment and its inhabitants. For these two reasons, plastic use and plastic pollution are urgent conservation issues that must be addressed.

The global demand for plastic puts pressure on our finite resources and plastic pollution is a serious threat to ecosystem and wildlife health. 275 million tons of plastic waste is produced each year and an estimated 8 million tons of this plastic waste enters our oceans annually[8]. Scientists believe this annual addition of plastic waste is adding to an already enormous amount of 150 million tons of plastic litter already deposited in marine environments[4].

However, plastics play an important role in our daily lives. Eliminating or substituting plastics with other materials would have substantial tradeoffs that must be considered. First, plastic is a light yet strong material. Using plastic instead of alternative materials results in lower fuel used and lower GHG emissions because of plastic's relative lightness and durability[3, 9]. Plastics also make it possible to extend the shelf life of fresh food and to ensure food is safe to eat. Substituting another material for food packaging could result in other environmental impacts from the sourcing of the substitute material. Food waste may increase if the material is not as effective as plastic at keeping food safe and fresh for consumption[9]. Plastics also have important applications within the healthcare system, such as maintaining sterility of medical devices and medications. The substitution of other materials for these functions could have high resource and human costs[10].

The elimination of some single-use plastics such as single-use straws, cups, and bags, is a good step forward in addressing our materials waste challenge. Identifying these plastics and working towards the elimination of unnecessary single-use plastics has become a more public and urgent issue in recent years and gained significant momentum in recent months[11, 12]. However, for less substitutable plastics, responsible sourcing will be necessary to reduce the negative impacts of the traditional plastic production process. Biobased plastic offers a potential substitute but evaluating the sustainability of bioplastic feedstocks is critical to ensuring that environmental, social, and economic benefits over traditional plastic are actually achieved. By recovering and reusing plastics multiple times through a system of cascading value we can do more with less. Secondary materials, those that have been used and recycled for reuse, offer the opportunity to reduce our environmental impact and recover economic value from materials otherwise considered waste. Finally, researching and implementing systems to reduce plastic leakage into natural environments will be necessary to reduce the global impacts of plastic.

PLASTIC POLLUTION

Plastic production has increased by about 10% every year since 1950 when global plastic production was just 1.5 million tons[13]. The annual global production of plastic is currently estimated to be near 275 million tons[4]. By comparison, 150 million metric tons are already present in our oceans and approximately 8 million tons is added to that every year[4].

In recent years public awareness of plastic pollution has increased dramatically. Plastic waste in marine environments causes issues such as entanglement and ingestion for wildlife at every level of the food chain[14]. Plastics can take hundreds of years to degrade, negatively impact water quality, and even cause human health

impacts through seafood contaminated with metal-tainted plastics[14, 15]. Southeast Asia is an epicenter for plastic waste leakage with half of the land-based plastic waste coming from China, Indonesia, the Philippines, Thailand, and Vietnam[16]. Rapid economic development in these countries have outpaced the development of waste management infrastructure that can support these new economies[16].

RESPONSE OF WWF

WWF recognizes the need for sufficient resources to meet the increasing demands of a growing population. Through informed decision-making and the responsible management of natural resources, WWF believes that the issues associated with plastic can be mitigated. The organization has developed two platforms through which we can reduce the impacts from the production and use of plastic. The Cascading Materials Vision and the Bioplastic Feedstock Alliance bring together companies, non-governmental organizations, scholars, and policy-makers committed to a future where we source and use plastics more thoughtfully and responsibly.

The Bioplastic Feedstock Alliance (BFA), led by WWF, explores the use and impacts of biobased plastics. BFA helps facilitate the use of credible science and critical thinking to responsibly evaluate bioplastic feedstocks. Members of BFA are committed to responsibly selecting feedstocks for biobased plastics and they are provided with technical tools and guidance to aid in their evaluation process.

Bioplastic spoon fork and biodegradable lunch box on banana leaf

Biopolymer with leaves and wood

The Cascading Materials Vision helps guide responsible decision-making for all materials. It advocates for improved accessibility and use of high-quality secondary materials. Systemic issues currently prevent the use of secondary materials in many industries.

Achieving large-scale re-use of materials could substantially reduce our use of virgin materials and help companies re-capture economic value in recycled materials.

> *The Cascading Materials Vision and the Bioplastic Feedstock Alliance bring together companies, non-governmental organizations, scholars, and policy-makers committed to a future where we source and use plastics more thoughtfully and responsibly.*

RESPONSIBLE SOURCING AND THE BIOPLASTIC FEEDSTOCK ALLIANCE

The Bioplastic Feedstock Alliance is led by WWF and comprised of some of the world's leading consumer brand companies. It is a collaborative, multi-stakeholder forum focused on increasing awareness around the environmental and social performance of potential feedstock sources for biobased plastics. Members of the BFA include: The Coca-Cola Company, Danone, Ford Motor Company, Nestle, Procter & Gamble, PepsiCo, Unilever, The LEGO Group, McDonald's Corporation, and Target Corporation. These global companies, together with respected academic and NGO thought leaders, are all committed to using informed science and critical thinking to help guide the responsible selection of feedstocks for biobased plastics to encourage a more sustainable flow of materials, helping to create lasting value for present and future generations.

While the bioeconomy offers promising solutions to some of today's pressing environmental issues, it has also brought into focus a number of critical issues such as resource competition for food, land, water and energy. These issues represent challenges to the future growth of the bioplastics industry as a part of that bioeconomy. BFA seeks to identify the potential impacts of the bioplastic industry and possible measures to mitigate them. In this way, BFA can help move the bioplastic industry's emerging supply chain in a positive direction.

WWF has developed a methodology with a clear goal of helping BFA members assess the supply chain risks associated with specific bioplastic feedstocks. This methodology was created to guide companies in finding feedstocks which have a more positive impact on the environment, society, and the economy. It is important to remember that, although biobased plastics address the sourcing impacts of plastics, biobased plastics may often meet the same end-of-life fate as conventional plastics. If biobased plastics are also littered into the natural environment or end up in landfills instead of a recycling facility where their value can be recaptured, these plastics can also have a significant environmental impact. Addressing the recoverability of plastics, whether biobased or not, remains a key challenge. This is where WWF's second initiative, the Cascading Materials Vision, comes in.

There is an urgent need to improve our material decisions and waste management systems to enable the re-use of materials so that they have cascading value across their life cycles.

MATERIAL RE-USE AND THE CASCADING MATERIALS VISION

WWF envisions a global system of efficient, cascading reuse of materials, allowing every business and industry to protect their profits, the environment, and the future wealth of our natural resources. The Cascading Materials Vision is a platform that seeks to enable a global system of efficient materials management. There is an urgent need to improve our material decisions and waste management systems to enable the re-use of materials so that they have cascading value across their life cycles. Led by WWF, the Cascading Materials Vision brings together the world's leading brands, policy-maker, materials management solution providers and environmental non-profits.

Ten foundational principles help guide industry leaders and other stakeholders in sourcing secondary materials. This common framework is used by WWF to influence relevant sectors toward achievable, sustainable, and inclusive solutions that address the systemic issues that prevent creation, trade, and use of secondary materials. The Cascading Materials Vision aims to inform decision-making that will expand the availability of high-quality secondary materials.

The Cascading Materials Vision is also used to educate policy-makers about systemic challenges facing secondary materials creation and use, and to serve as a basis for dialogue aimed at achieving practical policies to address these challenges. The Cascading Materials Vision serves as a foundation for promoting legislation that supports materials management programs that are socially, environmentally, and economically sustainable.

THE CIRCULAR ECONOMY

BFA and The Cascading Material Vision both fit within the framework of a circular economy which seeks to minimize waste and regenerate value throughout the lifecycle of the products and materials we use. The circular economy is also environmentally and socially responsible. To achieve a circular economy we must pursue design innovation and system improvement to be able to do more with

The Circular Economy

less. The circular economy includes the biosphere and the technosphere, illustrated by the left and right sides respectively of the figure on page 39. Because most materials degrade over time, new materials must still enter the system from the biosphere. Responsibly sourced biomaterials reduce our demand for non-renewable resources, ensuring new high value products still enter the system where necessary. Within the technosphere, it is imperative to recapture and reuse materials already in the system to reduce the overall demand for virgin materials and to ensure they are not being polluted into natural areas. Through its support of sustainably produced biomass and material reuse, WWF is helping producers understand their role and responsibilities in a circular economy.

INITIATIVES IN ACTION

WWF is proud to partner with leading organizations through BFA and the Cascading Material Vision to inspire action and encourage ambitious goal-setting. For example, in March 2018, BFA member the LEGO Group announced a new bioplastic initiative[17]. In addition to the LEGO Group's commitment to increasing carbon efficiency in the production of LEGO products and reducing CO_2 in the supply chain, and the company's purchasing of renewable energy which exceeds the amount of energy used globally by the company, the LEGO Group has now begun production of LEGO elements made from sustainable sources. Over 150 different LEGO elements, including botanical elements such as leaves, trees, and bushes are now produced from sustainably sourced sugarcane. Through its partnership with BFA, LEGO has ensured that the sugarcane used in the production of the biobased bricks is third party certified. This move exemplifies the opportunity that exists for the sustainable production of polyethylene. By 2030, the Danish company hopes to achieve zero waste to landfill and ensure all core materials and packaging are produced sustainably. The shift to biobased plastic for LEGO's botanical pieces is a strong first step towards the impressive goals of the company, and WWF looks forward to working with LEGO in its continued efforts to provide sustainable products without compromising on the high-quality play products the company is known for.

As a founding member of BFA, The Coca-Cola Company has led by example in its use of bioplastics[18]. The Coca-Cola Company has supported BFA in its work to identify and evaluate sustainable biofeedstock options. Through this research the beverage company has explored bioplastic options and developed a PET plastic bottle called PlantBottle. This bottle is fully recyclable and made with up to 30% plant material. This helps Coca-Cola reduce its use of petroleum, the non-renewable material traditional plastics are made from. Efforts are underway to commercialize a recyclable bottle that is made exclusively from sustainable materials but in the meantime, the company has set goals to drastically increase the amount of biobased materials and recycled content used for the production of new bottles. Coca-Cola's membership in BFA ensures that sourcing decisions related to biofeedstocks are carefully analyzed to provide the necessary information for informed and responsible decision-making.

Through involvement with the Cascading Material Vision, many global companies have launched material reuse initiatives and set ambitious goals for recycled content in their products and packaging. For example, Nestle has set a goal to reach 100% recyclable or reusable packaging by 2025. Further, Nestle has recognized its role in achieving a circular economy goes beyond its own production. Nestle has teamed up with local governments and Green Antz Builders, Inc. to produce construction materials from plastic waste. This collaborative project is based in the Philippines where eco-bricks (compressed, interlocking bricks made from shredded laminates) are produced. Production sites are expanding across the Philippines to cities such as Cagayan de Oro City, Cauayan, Isabela, and Baliwag. In addition to generating new and reliable products from waste, the production of eco-bricks provides jobs and income for local communities. This project exemplifies a good alternative to plastic's typical end of life which is either disposal or pollution. This program captures the value of material that would otherwise be considered waste and provides benefits to the local economy, thereby ensuring this program's long-term success.

CONCLUSION

Although plastic poses threats to our ecosystems, banning all plastics would have consequences for human health and safety as well as food waste. The materials substituted for plastic may also be associated with other serious environmental impacts. Plastics offer many benefits that alternative materials may not be able to provide without serious environmental implications of their own. Tradeoffs will be inevitable with any of these actions.

Eliminating plastics where possible and reducing the environmental footprints of the plastics we still use should both be actions we pursue. In addition, responsibly sourcing bioplastics and establishing a new system of material reuse together offer promising solutions to the pressing issues caused by plastics today. Responsible sourcing of new plastics must go hand-in-hand with the recycling and reuse of plastic because plastic degrades over time and cannot be infinitely recycled. Therefore, it will be necessary to replenish plastic with responsibly sourced bioplastic.

In order to reduce the negative impacts of plastic across its life cycle, the whole system must be transformed. Through its leadership of the Bioplastic Feedstock Alliance and Cascading Materials Vision, WWF is working towards a future where solutions to plastic issues are created and implemented worldwide. This work aligns with WWF's mission to conserve the world's biological diversity, ensure that the use of renewable natural resources is sustainable, and promote the reduction of pollution and wasteful consumption.

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2. VALUE AND LIMITATIONS OF PLASTICS

Plastic has become indispensable to our modern lifestyles. It helps to save energy, reduce CO_2 emissions and conserve resources. It has become vital to the food industry as it helps to cut food waste by increasing product shelf-lives. In the automotive sector, where plastics account for some 20% of materials in a car, plastics are used to cut vehicle weights and thereby improve fuel consumption. Similarly, plastics account for 60% of materials used in textile manufacture, a total of over 70 million metric tons of plastic annually. This reduces the need for natural fibers, such as cotton or wool, which require large areas of productive land that could be used to grow crops.

According to Trucost, the environmental cost of plastic in consumer goods is 3.8 times lower than that of alternative materials that would be needed if plastic was replaced. For example, it estimates that replacing plastics with alternative materials in passengers vehicles sold in North America in 2015 would lead to an increase in lifetime fuel demand for these vehicles of an additional 336 million liters, resulting in an environmental cost of $2.3 billion.

Once seen as a providential material, plastic is today more commonly seen as a time-bomb. The irony of this situation is that its initial advantages have morphed into the primary drawbacks: over 100 billion plastic bags are used every year in Europe while their lifetimes generally do not exceed 15 minutes – and it then takes 450 years for them to decompose in nature. Plastic pollution is now so prevalent in the ground and geological sediments that it has become a stratigraphic marker of passage to the Anthropocene, the post-18th century geological period characterized by the impact of human activity on the earth's ecosystems.

Plastic packaging generates significant negative externalities, estimated by the United Nations Environment Program at $40 billion annually, a greater amount than the profits made by the plastic packaging industry. Irrespective of the economic losses, the question of plastic's impact on the environment and human health is a major aspect of the controversies surrounding plastic today. Scientists have shown that the toxicity of plastic pollution, including nanoplastics, has a negative impact on marine animals. Take coral as an example. The risk of catching a disease rises from 4% to 80% for corals that have come into contact with plastic. Plastic debris is a vector for microbes and microorganisms, participating in the propagation of illnesses spread by invasive species and leading to functional problems in ecosystems.

The implications for human health of the presence of plastic fragments at all stages of the food chain are something that have not been sufficiently studied. Micro and nanoparticles of plastic have already been identified in drinking water supplies, honey, salt, seafood, the air and human digestive tracts, but we lack the ability to accurately gauge the negative impacts this contamination may engender.

Further scientific research, with a better worldwide coordination, is needed to increase our understanding of the spread of our plastic pollution and the impact this has on marine ecosystems and human health.

Fanny Arnaud
Review coordinator

ACCELERATING TRANSITION TO A CIRCULAR ECONOMY IN PLASTICS

Nicolas Grégoire and Igor Chauvelot
The "plastic cycle" team, Danone

Nicolas Grégoire joined Danone in 2006, where he contributed to the development of recycled PET use and set up an alliance to promote the development of bio-PET. He currently heads the company's 'plastic cycle' team in charge of ensuring the transition to a circular economy for plastics.

Igor Chauvelot is a graduate chemical engineer specializing in polymers. After having occupied several positions within Danone, he joined the 'plastic cycle' team in 2016, where he became responsible for defining and implementing the circular economy strategy for the company's packaging.

KEYWORDS
- PLASTIC CYCLE
- PACKAGING CIRCULARITY
- RECYCLED MATERIALS
- ECO-DESIGN

Danone is one of the world's leading food and beverage companies, whose products are used by millions of consumers. The company uses vast amounts of packaging, almost half of it made from plastic. Danone is committed to acting efficiently and responsibly to create and share sustainable value, and it recently unveiled a series of new commitments and actions to ensure the circularity of its packaging and accelerate the transition to a 100% circular packaging economy worldwide by 2025. This involves initiatives to improve product design and develop reusable packaging solutions, alternative retail and consumption models, investments to develop efficient and inclusive channels to increase collection and recycling, and actions to preserve natural resources by reintegrating recycled materials into packaging and increasing the use of renewable materials.

INTRODUCTION

A symbol of 20th century modernity, plastic revolutionized every business, and in particular the food industry. A lightweight, low-cost form of packaging, plastic improved food safety and reduced waste. Previously seen as innovative and a source of progress, plastic packaging is increasingly being challenged because of its environmental footprint. Plastic packaging currently accounts for 26% of total plastic waste volumes, and just 14% of plastic packaging is collected for recycling. Danone is fully aware of the seriousness of the problem, and is committed to accelerating the transition to a circular economy where packaging circularity is the new norm.

PLASTIC: CAN WE LIVE WITHOUT IT?

FROM GLASS TO PLASTIC

Danone's relationship with plastics is intrinsically tied to its history and recent developments.

Created in 1972 by the merger of Danone and leading European glass-maker BSN, Danone used to sell its products, yoghurts in particular, in glass containers. But when plastic containers appeared in the early 1980s, Danone gradually invested in this innovative material that had a carbon footprint considerably lower than glass. Today, close to half of the packaging used by Danone is made from plastic.

WELL-KNOWN ATTRIBUTES

For producers and consumers alike, plastic plays a key role in food product packaging. Inexpensive, lightweight and efficient, plastic reduces fuel consumption in transport due to its low weight and its barrier properties keep food fresh for longer, reducing waste as a result.

The Ellen MacArthur Foundation, a leading figure in the circular economy, acknowledges that plastic is useful but calls for it to be used responsibly, so that plastic packaging becomes a resource to be recovered rather than merely waste in the environment.

PLASTIC: THE GREAT CONTROVERSY

Long considered a precious ally to our societies, in the minds of consumers and policymakers alike, plastics have rapidly come to symbolize the threat that our consumption patterns pose to the environment, primarily in the form of environmental pollution. It is estimated that a third of all plastic packaging ends up in the environment and single-use packaging finds itself at the center of the debate.

Challenges related to plastic waste management have received extensive media coverage over the past decade, yet in less than three years the issue of plastics has come to top the environmental agenda in several parts of the world, overtaking concerns about climate change.

The explanation is simple enough. The most commonly encountered forms of plastic packaging are not sustainable because they are designed from a linear perspective: predominantly manufactured from virgin raw materials, they are used once then thrown away. This is a model that raises a slew of problems and requires a thorough re-working.

This is what is driving Danone to accelerate the transition to a circular economy by investing in innovative solutions and working closely with all the stakeholders – peers, governments, NGOs, innovative startups and the financial sector – to make packaging circularity the new norm.

THE CIRCULAR ECONOMY: A SOLUTION?

Danone is keenly aware of the environmental challenges that plastic represents and it has been working for several years to reduce plastic's impact on the environment.

The goal is clear: offer packaging that is 100% circular. To achieve this, Danone takes action to eliminate unnecessary packaging and innovates to roll out packaging that can be either reused, recycled or composted, as well as ensuring that the material produced stays in the economy and never leaches out to become a source of pollution.

RECYCLE OR REUSE: MUST-HAVES FOR THE NEW GENERATION OF PACKAGING

Tomorrow's packaging must be circular, meaning it must be designed not to transform itself into waste or a source of pollution.

In 2017, 86% of plastic packaging used by Danone could be recycled, reused or composted. Over half of all bottled water purchased worldwide was sold in reusable containers.

Danone has recently committed itself to offering 100% recyclable, reusable or compostable packaging by 2025. The company's Research and Innovation teams are fully mobilized to deliver this major technical and operational challenge. The heart of this research effort takes place at the Plastic Material Techno Center in Evian, in the foothills of the French Alps and the nerve center for the company's work on the plastics of the future, with further work taking place around the world through strategic alliances to invent the materials of tomorrow. Whether via scientific alliances or pre-market agreements, Danone is multiplying its collaborations to accelerate research and identify effective and sustainable solutions. It is a strategy that is paying off and the company has been able to identify highly promising technologies and approaches.

To support waste management and improve working and living conditions for waste pickers in Brazil, Novo Ciclo offers training as well as technical and infrastructure support.

Danone has ongoing initiatives to implement eco-design principles for packaging, like evian®'s pilot program to replace non-recyclable packaging film with specially designed adhesive points to keep together water bottles sold as a pack.

At the same time, Danone is working to design its products to optimize material use and limit waste. Danone is developing reusable packaging and new alternative retail and consumption models while also taking action to eliminate plastic packaging that is problematic (cannot be recycled) or unnecessary (provides no added value to the product or its protection). To this end, Danone is planning to introduce alternatives to plastic straws and will run a pilot program with its Indonesian brand AQUA in 2019.

CREATING THE CONDITIONS FOR AN EFFECTIVE CIRCULAR ECONOMY

Work on packaging design is essential, but alone this will not be enough to guarantee circularity. To achieve circularity and ensure that packaging is recycled, reused or composted in practice, effective and inclusive systems need to be put in place and fully operational.

Danone collaborates with public authorities and private partners to optimize extended producer responsibility (EPR) and deposit systems. In France, for example, Danone pioneered the EPR concept with the creation of Eco-Emballages, now known as CITEO.

In countries where recycling collection systems remain informal, Danone works with local communities, governments and partners – like the Inter-American Development Bank – to improve standards for waste collection and invest in recycling infrastructure. Danone and the Danone Ecosystem Fund have invested in inclusive recycling projects in seven countries, ensuring waste-pickers have a safe environment, appropriate remuneration and suitable welfare protection. As of late 2018, these projects have helped Danone to empower close to 6,000 waste-pickers, with over 45,000 tons of waste being recycled through these projects each year.

Danone brands also play a lead role in engaging with consumers and supporting research and innovation. For example, evian® is taking part in a research mission in partnership with The Ocean Cleanup, a Dutch nonprofit startup that develops highly promising innovative solutions to help rid the oceans of plastic. Danone's AQUA brand in Indonesia has committed to collecting more plastic than it produces, including retrieving plastic waste from the marine environment.

Danone also actively seeks to contribute to meeting or exceeding collection targets set by policymakers, such as the EU's target to achieve bottle collection rates of over 90% by 2025. Danone does this by supporting the most effective publicly organized systems and has set itself the goal of boosting its investments in private sector initiatives designed to reinforce circular economy infrastructures, particularly in countries where collection systems remain informal and those where there is a high risk of plastics ending up in the environment. Danone has recently invested over $5 million in the Closed Loop Fund, which develops large-scale recycling infrastructure in the United States, and is also looking to invest in similar initiatives, for example via Circulate Capital in Southeast Asia.

By 2025, Danone will have launched or supported collection and recycling initiatives in all its top 20 markets, which account for around 90% of its turnover.

PRESERVING NATURAL RESOURCES

Transitioning to a circular economy means no longer using packaging from non-renewable resources. This helps preserve natural resources and keeps existing materials in circulation. To deliver on this promise, Danone continues to strive to increase the proportion of recycled materials used in its packaging and to develop packaging manufactured from renewable materials. In 2017, Danone's packaging contained an average 36% of recycled materials and its bottles an average 14% of recycled PET.

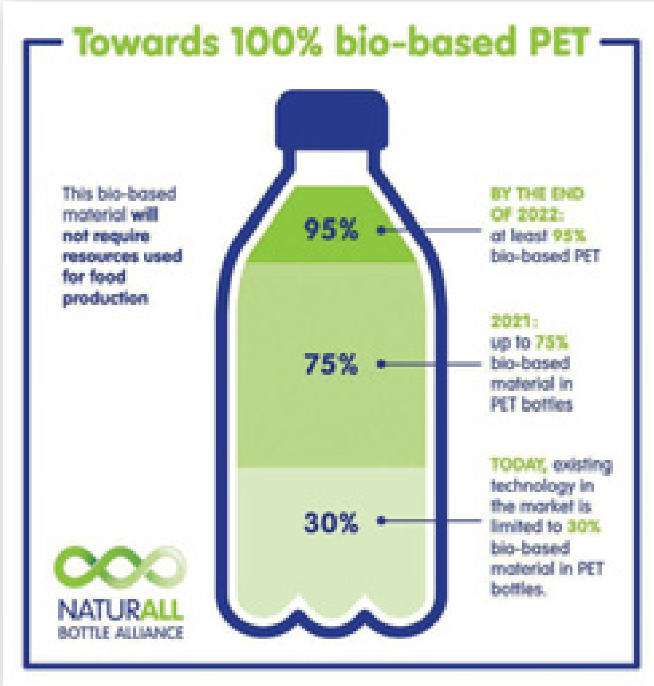
Danone is also investing in the development and use of renewable, bio-based materials to reduce its reliance on plastics from fossil fuels. Danone has partnered with Nestlé Waters, PepsiCo, and Origin Materials to introduce the first commercial-scale 75% bio-based bottle by 2021.

Danone intends to significantly increase the amount of recycled plastic and bio-plastic used in its packaging. By 2021, it will be offering 100% recycled PET bottles in all its major markets. By 2025, its plastic packaging will contain an average 25% of recycled materials, rising to 50% for bottles and 100% for evian® bottles. Danone will also strive to offer consumers bottles made entirely from bio-plastic.

ACTION HAS TO BE COLLECTIVE AND CONCERTED

Collaboration is the key to success in the circular economy. Fully aware of the importance of a systematic approach when fostering a circular economy, Danone has embarked on an open and collaborative innovation process. In 2015, Danone and Veolia agreed a strategic global alliance to explore together all forms of innovative solutions for managing water, plastics and waste. Highlights of this partnership include a new commercial model for purchasing rPET in Indonesia.

Fully aware of the importance of a systematic approach when fostering a circular economy, Danone has embarked on an open and collaborative innovation process.



More recently, at the Our Ocean Conference held on Bali, Danone signed up to the New Plastics Economy Global Commitment, sponsored by the Ellen MacArthur Foundation in collaboration with the United Nations Environment Program. Danone and the other signatories are committed to working to promote a new vision for plastic packaging.

CONCLUSION

Plastic packaging plays a fundamental role in preserving the nutritional qualities of food products. But some industrial groups, including Danone, are fully aware of the environmental challenges that plastics pose to the environment. Continuing to think in new ways about how plastic is used remains the priority so that its uses become circular, enabling society to continue to benefit from its advantages while reducing its environmental footprint. Transition toward a circular packaging economy will continue to evolve as we build new alliances, harness new technologies and develop new solutions. This is why, in 2017, Danone signed up to the New Plastics Economy initiative sponsored by the Ellen MacArthur Foundation. This mechanism has been joined by numerous food companies to promote an ambitious new vision of a circular economy for plastics by joining the New Plastics Economy Global Commitment as a sign of their concrete commitment to eliminating plastic pollution at the source.

CLOSED-LOOP POLYPROPYLENE[1], AN OPPORTUNITY FOR THE AUTOMOTIVE SECTOR

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Since 1994, Toni Gallone has been working within Renault Group, holding several positions, including R&D foundry, environmental management & risk prevention within Renault factories, recycling and circular economy development plan. He worked for the integration of recycled material within Renault engineering, developed new grades of recycled plastics in cooperation with Synova SA, industrialized the use of recycled fabric for car seat and initiated the industrialization of new composite pieces.

Agathe Zeni-Guido is an INSA Lyon science and materials Engineer (2015) and holds a environmental engineering and management specialized Master from ISIGE, Mines Paristech (2016). She has worked in the automotive industry alternately within Renault, Segula Technologies and Plastic Omnium. Her interest for environmental issues, more precisely in the recycling area, has urged her to use her knowledge about plastic materials for Renault Group within the framework of this study.

KEYWORDS

- END-OF-LIFE VEHICLES
- CLOSED-LOOP
- POLYPROPYLENE
- RECYCLING
- AUTOMOTIVE

1 Closed loop: a term used in the Renault Group to indicate that the recycling, collection, logistical, preparation and transformation operations are relatively short (geographical proximity and reuse in the same sector).

Every year, more than one million tons is used by European manufacturers alone. Second most commonly-used material in vehicles after metal, plastic is making up an increasing percentage of the composition of cars and is able to fulfil new technical functions thanks to high mechanical performance grades. However, recycling plastic is complex and the methods used (shredding, crushing, separation) are insufficiently selective, leading to substantial loss. The regeneration of automotive plastics, and polypropylene in particular, has enormous potential as a new supply source for the car industry that also ensures the regulatory requirements for End-of-Life Vehicles (ELV) recovery are met.

In light of this, the Renault Group has launched a study looking to increase the yield and value of transforming polypropylene (PP) materials, in the framework of its proactive approach towards incorporating recycled materials in its vehicles. The study has highlighted several crucial points for introducing an optimised processing and separation line for recovering plastics. Optimising the processing and separation framework helps boost the competitiveness of these recycled materials. Increased PP recovery yields thus lead to higher profitability, a stronger recycling value chain and a doorway to the development of new technical grades.

INTRODUCTION

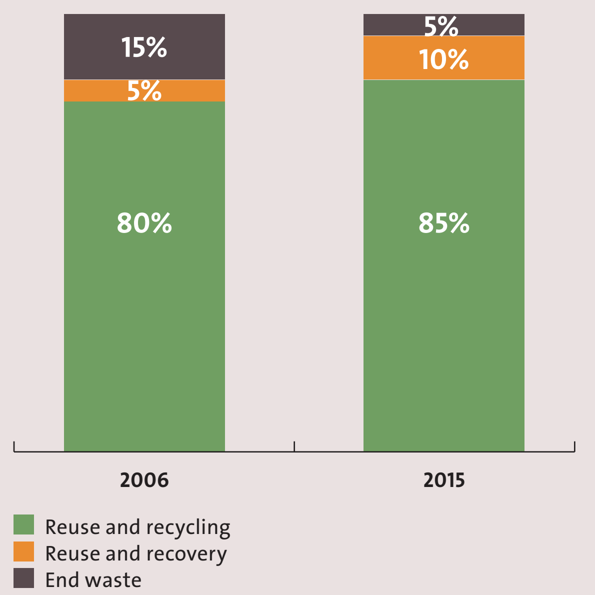
Plastic, the second most commonly-used material in vehicles after metal, is making up an increasing percentage of the composition of cars and is able to fulfil new technical functions thanks to high mechanical performance grades. However, recycling plastic is complex and the methods used (shredding, crushing, separation) are insufficiently selective, leading to substantial loss. In light of this, the Renault Group has launched a study looking to increase the yield and value of transforming polypropylene (PP) materials, of which the automotive industry is a major consumer – every year, more than one million tons is used by European manufacturers alone.

The recycling of PP (polypropylene) plastics relies on the involvement of certain companies and scientific bodies who are working towards developing a French industrial sector for technical products made of recycled plastics taken from end-of-life vehicles. These industrialists have agreed to work together and share their best techniques in order to develop viable and profitable solutions.

AMBITIOUS REGULATORY OBJECTIVES

Once they reach the end of their service life, End-of-Life Vehicles (ELVs), deemed hazardous waste in regulatory terms, must be decontaminated and recycled. In order to meet the requirements of European Directive 2000/53/EC, as of 1 January 2015 handlers are obligated to reuse 95% of ELVs overall: 85% recycled and 10% for generating energy. In line with the principles of Extended Producer Responsibility (EPR), car manufacturers must design and promote processes for managing the waste created by their products.

End-of-Life Vehicles recovery targets
according to the 2000/53/EC directive



The Renault Group has taken a proactive approach towards incorporating recycled materials in its vehicles since the Megane II, using an average of 30% recycled materials at the end of 2014. It has also set the bar for recycling End-of-Life Vehicles (ELVs) via Indra and the Life+ “Icarre 95” project (industrial demonstrator to achieve 95% recycling of ELVs) and also for implementing circular economy schemes (remanufacturing of parts, parts for reuse, material closed loops, etc.).

MATERIAL COSTS - THE KEY TO COMPETITIVENESS

The cost of raw materials affects the price of recycled materials. As it stands, the recycled plastics market is not yet mature and prices are not entirely correlated with the technical reality – rather than reflecting the transformation costs, they are mostly indexed against the price of virgin resin. Recycled materials are only preferred when they cost equal to or less than the virgin material. In response to these issues, the Renault Group is actively working to develop and optimise the recycling channels for ELV recovery. Over one million ELVs are processed in France every year, the equivalent of more than one million tons of potentially usable material. There is a dual objective here: increase the recovery of End-of-Life Vehicles and increase the amount of recycled material available for use in new cars.

The strategy developed by Renault to tackle this forms part of the circular economy.

IMPROVING CLOSED LOOPS FOR POLYPROPYLENE (PP)

There is a growing demand for recycled plastics in the car industry. However, more than 80% of the available resources are currently derived from manufacturing scraps. Renault’s vision is to offer an alternative made using waste from its own industry: End-of-Life Vehicles (ELVs). This is what is referred to as closed loop recycling, as opposed to ‘open loop’ where the recycled material is used in another industrial sector. The Renault Group began using recycled plastic in its vehicles in the 1990s. In 2011, it went one step further and introduced closed loops for reusing parts and materials through its Icarre 95 project, which was co-funded by the European Life+ programme. Channels were developed, from collection to the end product, for three categories of material: plastics, metals and foams & textiles. The closed loop developed for polypropylene (PP) plastics consists of transforming car bumpers (fenders) and wheel arch liners into directly reusable material that can be injected into new car parts. End-of-life parts are compacted into bales to facilitate transport, and are then shredded and placed in a floating tank to separate the different plastic qualities according to their density. The sorted material is then compounded: charges, additives and/or virgin material are added to improve the plastic’s technical properties so that it meets client specifications.

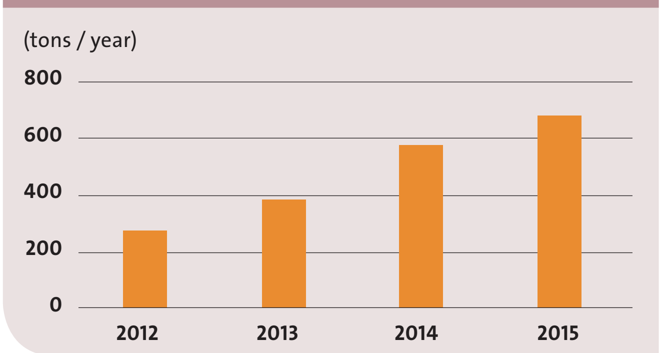
Car bumper bales

The PP closed loop is the result of close cooperation between a variety of stakeholders, with each contributing their own specific skillset:

- Indra for dismantling materials: a joint venture between Renault and SITA/Suez Environment that specialises in car deconstruction.
- Synova for developing and transforming materials: a chemical transformer that creates compounds using recycled material from car bumpers.
- Workshops in Renault concessions: these recover End-of-Life Parts (ELPs) from the vehicles they repair. They supply the recycling loop with its raw material.
- Gaia, coordinator and participant in material preparation: a subsidiary wholly owned by Renault, Gaia manages the logistics and sales of material produced by the Group's circular economy model. It also ensures that the process meets the requirements of all other contributors in the chain.

The volume of PP collected by Gaia increases every year. The 680 tons of PP recovered in 2015 is the equivalent of almost 42,000 vehicles, from which the front and rear bumpers were taken as well as the wheel arch liners.

Annual volume of PP collected



THE OBSTACLES TO RECYCLING POLYPROPYLENE

Preparing the material generates significant losses, both when shredding and drying the material, but most of all during the floating stage. The density measurement method is used to separate the different grades of plastic, but it is beset with a host of difficulties. First and foremost, the density ranges for different plastics are concentrated between 0.9 and 1.4. Furthermore, the presence of charges in the materials, such as mineral charges, natural fibres or glass fibres, increases the density of the material that will flow out during floating. A considerable amount of PP (charged above 15%) will thus flow into the 1.02 density tanks, which is the same density as dirty water and the value normally used in flotation facilities. The flow fraction is deemed waste and is removed from the recycling process.

The processing flow currently used by most recyclers is almost entirely based on density measurements, and the flow-off is hardly recycled, if at all. This means that, on average, one quarter of the material fed into the closed loop is discarded. This is a significant loss that carries a dual cost: firstly for its purchase, transport and processing, and secondly for managing its end of life through storage or energy conversion.

Future research into optimising the processing and separation of vehicular plastics must focus on achieving the highest material recovery rates possible, while still maintaining high end-product quality. In order to optimise these areas we need to know the characteristics of the inflow, so that the separation process can be adapted to recover all of the desired materials and remove any others.

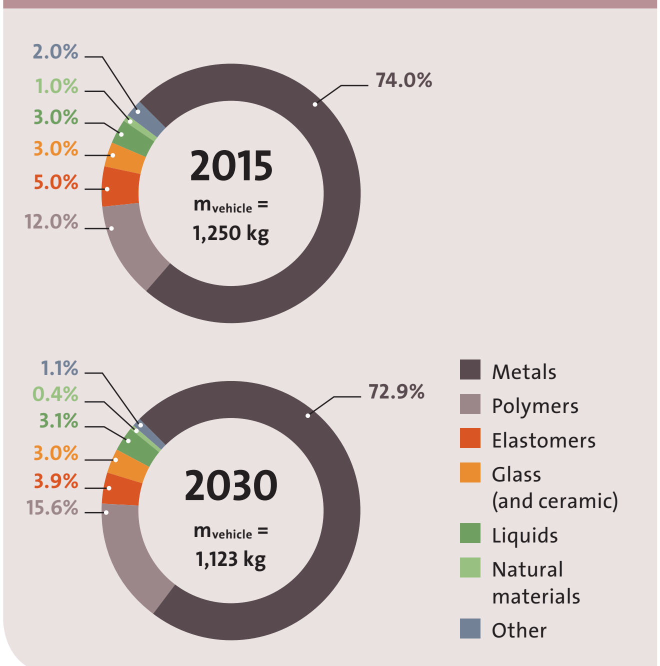
WHAT WILL OUR END-OF-LIFE VEHICLES LOOK LIKE IN 2030?

The average age of the vehicles delivered to ELV centres is gradually increasing: in 2014 it was 17.5 years. This means that vehicles currently on the market will reach the end of their service lives sometime around 2030.

A compositional analysis of recent vehicles has shown how the composition of future ELVs is likely to change compared to now - they will contain an average of 25 kg more plastic. These estimates take into account the growing use of plastics in the automotive industry, often as a substitute for parts that were previously made from metal, but also as decorative and/or useful parts in the car interior.

However, it must be possible to clearly distinguish between the easily removable portion composed of homogeneous plastics, and the more diverse portion comprising multi-material plastics, metallic inserts, elastomers, etc.

Estimated composition of End-of-Life Vehicles



What will our End-of-Life Vehicles look like in 2030?

FOCUS ON THE CAR BUMPER

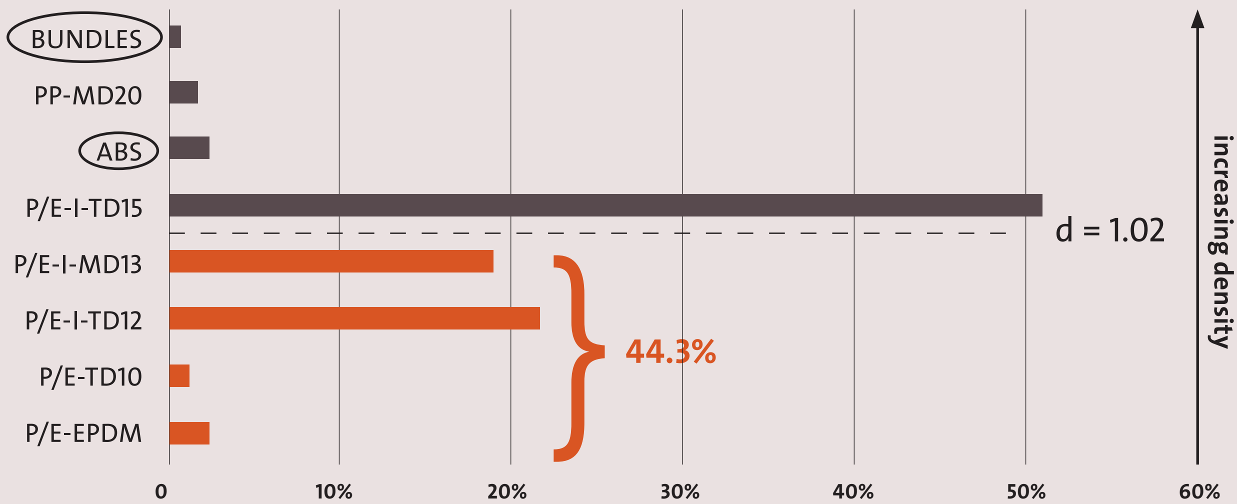
The car bumper is a compulsory safety feature on all vehicles. Located at the bottom of the bodywork on the front and rear, it is made from deformable material in order to cushion against impact. In general it is made from plastic, but its composition and appearance varies - it may be painted the same colour as the bodywork, there may be chrome or aluminium inserts, or it may be adorned with decorative parts.

A study into the composition of car bumpers in different makes and models has shown that they are almost exclusively made from polyolefins[2] (over 91%), and this is true for both front and rear bumpers. This high concentration is a crucial fact when it comes to recycling the materials in these parts, especially since the same is true for several vehicles from different manufacturers.

For example, only 44.3% of the material in the front bumper of the Renault Captur has a density of less than 1.02, which means that 4.7 kg of material will flow out into the tank and thus be wasted.

2 Polyolefins are a category of polymers that include polypropylene (PP) and polyethylene (PE). They have the special ability of being able to float on clean water (density less than 1).

Composition of the Renault Captur front bumper



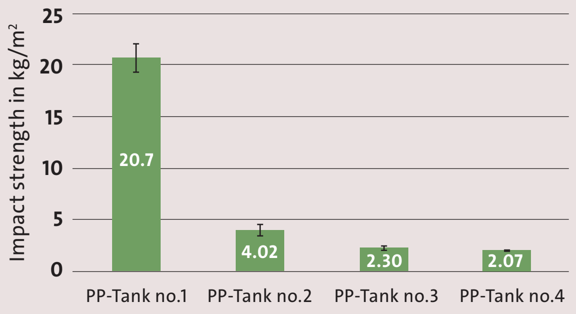
A NECESSARY CHANGE IN PROCESSING METHODS

The study estimates that, if a batch of bumpers from multiple manufacturers of future ELVs were processed in 2030 in the same way as they are today, there would be an additional average loss of 9.5% of material. Therefore, if no changes are made, material recovery yields will inevitably decrease in the future. This situation will worsen over time, so we need to start thinking now about how to change the shredding/washing/floating process in order to reduce wastage and improve recycling of PP from ELVs. The study proposal focuses on eliminating impurities: styrenic polymers[3], foams and films. Styrenics have a damaging effect if they are left in the final PP compound, dramatically reducing shock resistance for example.

To remove these unwanted substances, it may be worthwhile investigating the use of airflow technology such as the zigzag or densimetric tables. Another suggestion is the use of electrostatic separation to over-separate the flow products. This technique can sort particles according to the charge they acquire, instead of density as is usually the case. However, the biggest problem would then be the overlap between polymer density ranges (and other elements that need to be removed, such as elastomers or wood).

Charpy impact test 1eA

Result of Charpy test sample reactions to impact, taken from four batches

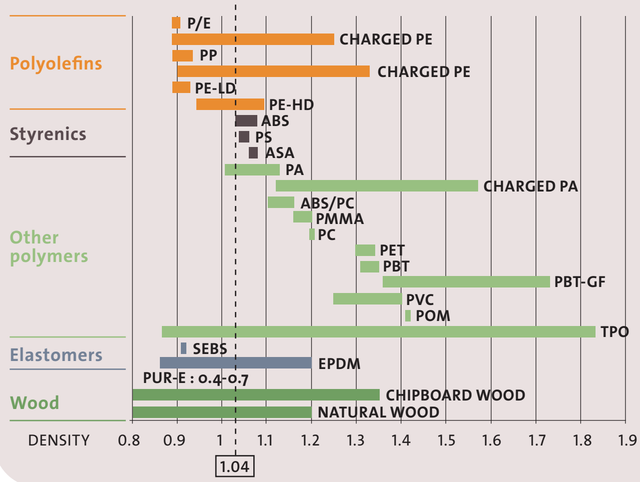


The mean density of samples increases (1.008/1.046/ 1.052/ 1.056) with the density of the separation tanks.
Impact resistance is more than quartered between tank 1 and the others, which is due to a higher tank density in tanks 2, 3 and 4 causing styrenic materials to float.

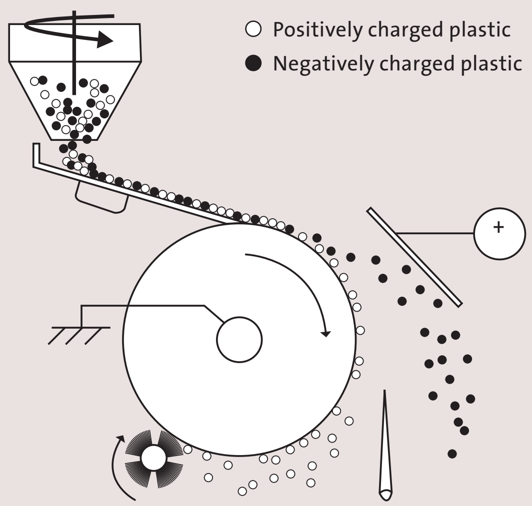
Electrostatic separation relies on the ability of particles to become positively or negatively charged. There are two ways to do this: subject them to an electrical field (corona charge) or stimulate intense friction between them (electrostatic charge). The former is suitable for separating conductors from non-conductors, whereas the latter works better when separating plastics. In either case, it is imperative the materials being processed are clean and dry (moisture less than 0.1%). The size of the fragments varies between 1 mm and 1 cm.

The use of this technique would result in a number of flows that need to be recycled separately. This could prove useful in reducing the amount of waste generated and may pave the way to a new opportunity – creating a market for regenerated charged PP. In addition to this, ABS that is also contained in the floating flow-off could be recovered in the same way, and could benefit from similar technical advances as those for PP.

Overlapping of density ranges



Principle of electrostatic separation



The plastic particles are friction-charged inside a rotating drum. They exchange their electrons with each other, with one material becoming positively charged and the other becoming negatively charged. The - charged particles are attracted to the + charged electrode.

Source: http://www.hitachizosen.co.jp/english/technology/hitz-tech/material.html

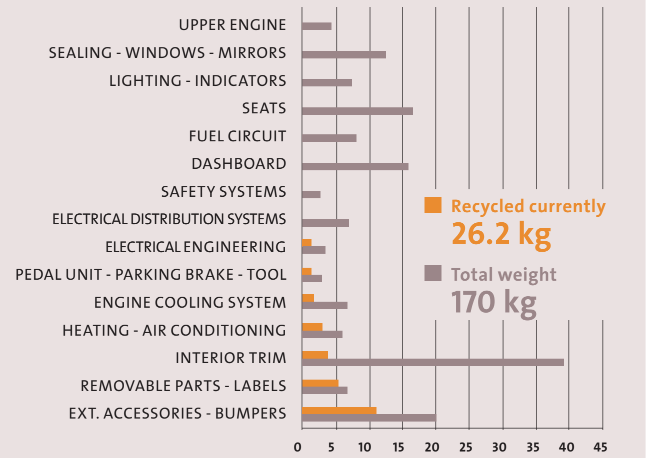
3 *The category of styrenic polymers includes all polymers derived from styrene monomer, such as polystyrene (PS), acrylonitrile butadiene styrene (ABS) and acrylonitrile styrene acrylate (ASA).*

PROCESSING MULTI-SOURCE FLOWS

Plastic obtained from parts of dismantled ELVs must be processed in addition to other sources so as to increase the flows as much as possible, make use of the line's maximum processing capacity, and improve the benefits of optimising the separation line. This must be accompanied by higher customer demand for recycled materials.

The increase in "inbound" volumes could come from Waste Electrical and Electronic Equipment (WEEE) or from waste packaging, such as those from expanded household waste sorting guidelines (plastic containers, plastic film, yoghurt pots, etc.). Such waste could be processed on the line in different campaigns. These sectors are also facing the same issues - a range of materials within the same product and separating mixed materials at end of life - even if the polymer resins used are vastly different from those used in the automotive sector.

Weight distribution of virgin and recycled plastics in the restyled Renault Clio IV (2016)



Source: Gérard Liraut

RECYCLED RESINS FOR MORE TECHNICAL USES

For the moment, recycled plastics are mostly used for parts that are not overly technical or visible. When the flows of materials for transformation or transportation have relatively little value, it is harder to be competitive (due to fixed transport costs). It may therefore be worthwhile concentrating on higher added value applications, such as parts visible inside the vehicle.

Permissible output quality becomes essential for technical grades, and the problems encountered differ depending on whether the part is designed for the interior or exterior of the vehicle:

- for validation of visible materials inside the car, the appearance (colour and texture), odour, and VOC emission characteristics must be controlled;
- for exterior accessories, the hurdles are more linked to paintwork and durability (aging, sun exposure, paint adhesion).

In both cases, the fluidity of the material must be checked to make sure parts are usable if made from these recycled materials.

For example, in the restyled Clio IV (2016), recycled plastic is the main material used in bumpers and wheel arch liners. Conversely, the interior trim of the Clio, which is the obvious application with almost 40 kg of plastic, contains very little recycled material. There is therefore much room for improvement, and in particular a significant opportunity for developing technical polymers from recycled materials. This change will only be possible if certain processing rules are adhered to, namely the exclusion of soiled PP materials (batteries, fuel tanks, automotive shredder residue) and unwanted plastics (PUR, POM, PMMA, styrenics).

Automotive plastics have a wide range of applications, all with have varying levels of technical requirements. It would be worth developing different material qualities in order to minimise losses during separation, and offer applications for a diverse range of uses. However, automotive specifications remain extremely stringent, and numerous criteria must be met before recycled plastic materials can be used in this sector.

LESSONS LEARNED FROM THE STUDY

The study has highlighted several crucial points for introducing an optimised processing and separation line for recovering plastics:

- the necessity for a large volume of plastic to process;
- multiple sources: ELVs, WEEE, household waste, etc.;
- in-house expertise in the use of equipment such as floating, densimetric tables, and electrostatic separators;
- obtaining flows of varying qualities to minimise losses;
- finding applications for these flows: shredded/floated PP as well as ABS and charged PP flows;
- connection to a compounder capable of transforming the obtained flows for specific client requirements.

CONCLUSION

The regeneration of automotive plastics, and polypropylene in particular, has enormous potential as a new supply source for the car industry that also ensures the regulatory requirements for ELV recovery are met. Optimising the processing and separation framework helps boost the competitiveness of these recycled materials. Increased PP recovery yields thus lead to higher profitability, a stronger recycling value chain and a doorway to the development of new technical grades. As a consequence, recyclers see their revenues increase, Renault loses less material, and the developed grades can be applied to the 52,000 tons of recycled plastic used by the Group every year. The ultimate goal is to sustainably increase tonnage.

MICROPLASTICS IN OUR OCEANS AND MARINE HEALTH

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KEYWORDS

- MICROPLASTICS
- MICROBEADS
- MARINE BIOTA
- MARINE HEALTH

If the 20th century was the revolution era of plastic industry for manufacturing too many plastic based products starting from bucket to car, then the 21st century is the time to face its consequences. Improper management, lack of information about its negative effect and irresponsible use as well as dumping of plastic products turns this planet into "plastic planet". Besides emerging as solid waste, these plastic materials also appeared as a great threat for human and animal health. It not only polluted the roads, forests, mountains but also polluted our oceans. Ignorant human populations always throw the plastic waste into water bodies and most probably the *"out of sight out of mind"* thought leads them to do so. This is why the problem of microplastics in the marine ecosystem is an issue of great concern nowadays.

Here we discuss the different sources of microplastics in the oceans and their harmful impacts on the marine organisms. The microscopic size of these plastic fragments gets them easily available for ingestion by an array of marine habitants, causing adverse effects on their health. The potential of microplastics to absorb various harmful hydrophobic pollutants from the surrounding environment indirectly transfers these contaminants in the food chain. Thus to tackle this serious issue of microplastic pollution in the marine ecosystem, various policies and rules must be formulated. To avoid future threat, it is important to stop producing it further and replace the plastic with alternative eco-friendly materials.

INTRODUCTION

The fabrication and utilization of plastic over the last few years have been drastically increased due to its cost benefit nature and this has resulted in the increased disposal of these non recycled (treated) synthetic plastic polymers in the terrestrial and aquatic ecosystem[1]. The small plastic fragments disposed in the marine habitat having dimensions ≤ 5 mm are defined as microplastics[2]. These tiny plastics can be consumed by different marine biota including corals, planktons, marine invertebrates, fish and whales and are ultimately transferred along the food chain[3]. These plastic polymers directly pose a great threat to marine organisms and also indirectly affect the ecosystem by adsorbing other marine pollutants. Due to its large area to volume ratio, microplastics are readily absorbing hydrophobic pollutants from the aquatic system. Thus microplastic pollution is becoming an issue of concern because of its detrimental effect mainly on the marine health and biota.

MICROPLASTICS

Plastics are synthetic polymers which are supple or malleable (flexible) in nature and can be transformed in different shapes. Plastic is composed of long chains of polymers which are composed of carbon, oxygen, hydrogen, silicon and chloride and are acquired from natural gas, oil and coal[4]. The most prominent synthetic plastics are polyethylene (PE), polypropylene (PP), polystyrene (PS), polyethylene terephtalate (PET), polyvinyl chloride (PVC), low density polyethylene (LDPE) and high-density polyethylene (HDPE) and constitute 90% of the worldwide plastic production[5]. The properties of plastics such as flexibility, durability, low cost, easy to handle (lightweight) and resistant to corrosion makes it a widely acceptable compound. Plastic can withstand high rate of electrical and thermal insulation and thus have tremendous industrial and commercial usage[6]. There has been an exponential increase in plastic production from 1950 (1.5 million tons) to 2015 (322 million tons)[7]. The disposal of plastic materials is an issue of concern these days because of its durability and corrosion resistance. Plastic compounds take up to years to get degraded in smaller fragments[8]. Larger plastic debris slowly degrades into small fragments with various size ranges extending from meter to micrometer due to changing environmental conditions. This fragmented plastic with size smaller than 5 mm are known as microplastics[9] and are highly persistent in the ecosystem. Based on shapes, sizes and chemical composition, microplastics can be differentiated as follows.

TYPES OF MICROPLASTICS

On the basis of origin, microplastics are categorized in two types: primary and secondary microplastics[10]. Primary microplastics are micro-sized synthetic polymers and used as exfoliates of various processes such as chemical formulations, sandblasting media, maintenance of various plastic products and also in the manufacturing of synthetic clothes. Microbeads are another type of primary plastics (size < 2 mm) composed of polyethylene (PE), polypropylene (PP), polystyrene (PS) beads and are used in cosmetic and health care products. Secondary microplastics are the fragmented product of macro or meso plastics and mostly generated under the effect of various environmental processes such as biodegradation, photodegradation, thermo-oxidative degradation, thermal degradation and hydrolysis[3] (Figure 1). Further nanoplastics are plastic fragments with < 1 µm size, and all these microplastics and nanoplastics have potential implications for the bioamplification and bioaccumulation of various chemicals and pollutants due to their large surface to volume ratio[11].

Diagrammatic representation of different types of plastics and their effect on marine organisms

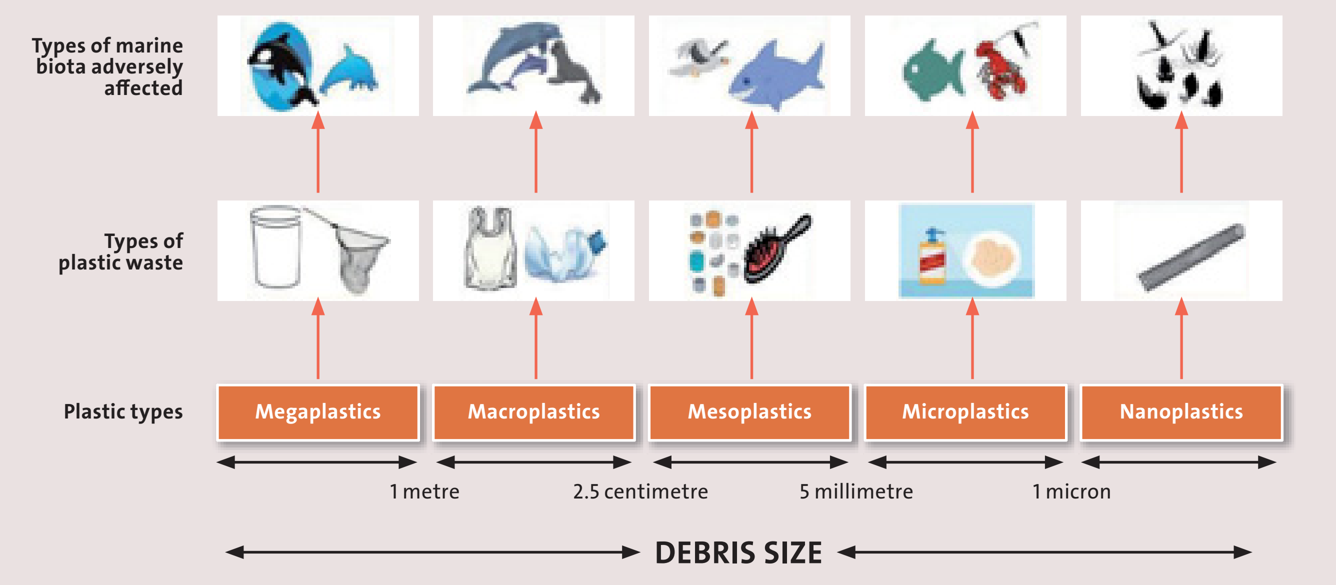

Figure 1

SOURCES OF MICROPLASTICS

The presence of these hazardous plastic fragments in the ecosystem (terrestrial and aquatic) is due to different anthropogenic activities which include domestic, industrial and coastal activities. The introduction of microplastics in the aquatic ecosystem is mainly because of the domestic runoff which contain microbeads and microplastic fragments (used in cosmetic and other consumer products) and also from the fragmentation of the large plastic trash[12]. The plastic manufacturing industries release plastics in the form of pellets and resin powders produced from air-blasting[13] which ultimately contaminate the aquatic environment. Also the coastal activities which include fishing practices, aqua tourism activities and marine industries are the sources of microplastic pollution in the marine ecosystem.

> *Microplastics also adversely affect planktons which are a most essential component of the marine habitat*

Microplastics once entered in the marine habitat are exposed to different physic-chemical processes such as biofouling and leaching or incorporation of secondary pollutants. Microplastics have different shapes, size and density, and according to these features, plastic fragments have distributed in different compartments of the marine ecosystem (finally settle down to benthos) and are available for the marine biota[3].

The pelagic marine biota which consists of planktons and crustaceans are exposed to low density microplastics whereas benthic organisms such as polychaete and tubifex worms, amphipods and mollusks are known to encounter with dense microplastics[14]. The settling rate of microplastics through the water column varies depending on different factors such as polymer type, biofouling and surface chemistry of the particles[15]. In most of the studies, microplastics have been detected in benthic environments and sediments. Benthic environment is one of the significant feeding ecosystems for a range of marine biota. Recent studies have shown that marine benthic biota ingest microplastics which is present in the sea in the form of microbeads and microfibers[16].

EFFECT OF MICROPLASTICS ON THE HEALTH OF MARINE BIOTA

These tiny plastic fragments are persistent in the marine ecosystem and due to their micron sized particle nature, these fragments are mistaken as food and ingested by a range of marine biota which includes corals, phytoplanktons, zooplanktons, sea urchins, lobsters, fish etc. and ultimately get transferred to higher tropic level. The impact of microplastic on marine biota is an issue of concern as it leads to the entanglement and ingestion which can be lethal to marine life. The microplastic fragments mainly arrive from terrestrial source and thus coastal ecosystems which comprise of coral reefs are in great threat due to microplastic pollution. Corals survive in a symbiotic association with single celled algae which is present in the tissues of corals cavity. The algal association is a source of energy through the process of photosynthesis. Also corals obtain energy by feeding on planktons to acquire important nutrients which are essential for their growth, development and reproduction[3]. The 'microplastic feeding' mechanism of corals involves ingestion, retention of plastic fragments and digestion[17]. The harmful effect of microplastics on corals involves retention of plastic fragments in mesenterial tissue which leads to reduction in feeding capability and lowering in energy reserves[18].

The microbial biofilms associated with microplastics may also negatively regulate coral reef by promoting pathogen transmission[19]. The first report of presence of microplastics in scleractinian corals was detected in the Australia's Great Barrier Reef. The experiment of feeding trials of corals revealed that corals when exposed to microplastics consume these tiny fragments at a rate of ~50 µg plastic cm^{-2} h^{-1}. These ingested plastic fragments were detected in the mesenterial tissue within gut cavity of coral which have negative effect on coral's health[20].

Microplastics also adversely affect planktons which are most essential component of the marine habitat. The penetration of microplastics along the cell wall of phytoplanktons results in the reduction of chlorophyll absorption[21]. Also the heterotrophic plankton when exposed to microplastics undergoes the process of phagocytosis and retains these tiny plastic fragments

in their tissues[22]. Zooplankton (a class of marine invertebrates) have essential role in marine ecosystem as these microorganisms are basic primary consumers of aquatic food chain. Zooplanktons have a range of feeding mechanisms and utilize the mechanism of chemo-mechano receptors for prey selection[23]. The omnipresent nature of microplastics in marine habitat results in the interactions of microplastics with these zooplanktons as both of these are of same dimensions (> 333 µm) resulting in highly possible interactions[24]. Experimental studies revealed that zooplankton were found to ingest latex beads when exposed to microplastic[25]. In another study, it was found that zooplankton has the tendency to ingest polystyrene beads of dimensions of 1.7–30.6 *µ*m. The *Centropages typicus*, a well known copepod was known to ingest microplastics (of size 7.3 µm) and ultimately lost their feeding ability which consequently has negative effect on their health[24]. The effect of microplastics on *Gammarus fossarum* leads to decrease in the growth of this organism when exposed to poly (methyl methacrylate) (PMMA) and polyhydroxybutyrate (PHB)[26]. Also, the ingestion of polyethylene (PE) microplastics in benthic organism *Hyalella azteca* leads to decrease in the growth and reproduction process[27]. The microplastics uptake in the marine lugworm *Arenicola marina* caused reduction in feeding capability and ultimately weight loss[28].

Certain features of microplastics such as microscopic size, attractive colors and their high buoyancy makes these tiny fragments easily available for fish. Fish ingest microplastics by mistaking these fragments as planktons or other natural prey. In a study, the microplastic ingestion was found in the planktivorous fish *Acanthochromis polyacanthus* where microplastics of the dimensions < 300µm was present in the gut cavity of individual fish[29]. In one of the experiments, ingestion of microplastics by fish showed that exposure of these plastic fragments causes histopathological modifications in the intestine, resulting in the detachment of mucosa epithelial lining from the lamino propia and causing its widening, reduction and puffing of villi, increase in number of globet cells and certain alterations in the normal structure of serosa of fish[30]. The effect of polystyrene on a European fish (*Perca fluviatilis*) was studied in which eggs and larvae of *Perca fluviatilis* were exposed to different concentration levels of microplastics found in the Swedish coast, namely 10,000 particles per m^3 and 80,000 particles per m^3. It was found that eggs which were exposed to high concentration of microplastics had a comparative slower hatching rate when compared to control. Also the larvae exposed to microplastics were smaller and slower in comparison to normal larvae. The responsive ability of microplastics exposed *Perca fluviatilis* larvae to the chemical alarm (existence of predator) was found to be very low and thus it has a deleterious effect on the survival rate of fish. Other study also showed that microplastic ingestion in fishes cause metabolic alterations which include up-regulation and down-regulation of fatty

acids and amino acids respectively[31]. The ingestion of micro and nano plastics causes alteration in the ratio of triglycerides and cholesterol in the blood serum level of fish and also causes variation in the delivery of cholesterol between muscle and liver of fish[32].

The harmful effects of microplastic ingestion is an issue of concern specially in case of sea birds as half of the species are endangered and the toxic effect of plastic fragments has negative effects on their body which could cause alteration in the feeding behavior, reproduction and mortality[33]. It was found that six species of sea birds, *Phalacrocorax bougainvillii*, *Pelecanoides garnotii*, *Pelecanoides urinatrix*, *Pelecanus thagus*, *Spheniscus humboldti* and *Larus dominicanus* have the plastic fragments in their stomach region and maximum ingestion capacity was detected in case of *Larus dominicanus* which commonly feds upon fishing nets, waste disposal products and plastic containers[34]. The ingestion of plastic debris by these species mainly depends on certain factors such as size, weight and habitat of the sea birds; e.g. the species of sea birds *Spheniscus penguins* and *Thalassarche albatross* have small body size and thus ingestion rates were lower in comparison to large sea birds. The species such as *Fulmarus fulmars*, *Cyclorhynchus auklets*, *Oceanodroma*, *Pachyptila prions* and *Pelagodroma* have higher ingestion rate of plastic debris due to their large body size and weight[33]. The large creatures of marine biota which includes sharks, whales, seals, sea turtles and polar bears are also vulnerable to microplastics ingestion in the oceans throughout the world; e.g. the presence of microplastics was detected in the stomach and intestine of harbor seal, *Phoca vitulina*[35]. This class of marine mammals is filter feeders and thus ingests substantial amounts of microplastics either directly swallowing from ocean water or indirectly by consuming prey containing microplastics in their body cavity. The presence of the microplastics in the stomach of sharks of Sea of Cortez and whales of Mediterranean Sea proved that most of the littered plastic waste worldwide ultimately ends up at sea[36] and imposed a great threat to marine animals. In a study done on Mediterranean fin whale (*Balaenoptera physalus*), high concentration of phtalates were detected in these baleen whales which indicates the severity of microplastic pollution in world ocean[37].

The large creatures of marine biota which includes sharks, whales, seals, sea turtles and polar bears are also vulnerable to microplastics ingestion in the oceans throughout the world.

CONTROL MEASURE

The worldwide record of plastic litter entering in the ocean gyres was estimated to be 4.8 to 12.7 million metric tons, and with the increased use of plastic and its products, the total amount of plastic litter available to marine ecosystem is expected to increase substantially by the end of 2025[38]. This major issue was also raised in the “16th Global Meeting of the Regional Seas Conventions and Action Plans” which was held to literate nations regarding worldwide threat of plastic pollution in the marine habitat, and financial damage of approximately US$13 billion per year to the marine ecosystem was estimated[39]. Considering this recent trend of ocean pollution by plastic litter, there is a pressing need to carry out some dedicated research which could help to restrict plastic pollution and could clean different water bodies worldwide. Certain innovative measures should be taken by states to literate the society about the harmful effects of plastic debris in the marine ecosystem. It is very essential to introduce certain strong legislative rules and policies which could monitor the excessive use of plastic items, otherwise the health of ecosystem will worsen in the coming span of time[3]. There should be a well established waste collection system which could check the collection of waste containing plastic litter. Efficient management, recycling and finally environment friendly disposal system would help in making environment free from plastic. Substantial policies are formulated in developing countries against the use of plastic and its product such as complete ban on plastic bags and plastic bottles and imposing fine on usage of plastic[40]. However, unfortunately FMCGs are still using plastic packets for selling their products. There should be a complete ban on microbeads in cosmetic and other personal care products such as toothpastes, face wash and shampoos. The waste management schemes such as EPR (extended producer responsibility) which promote the use of manufacturing packaging materials other than plastic for food and other beverage packaging should be encouraged. Various campaigns should be organized by various governmental and nongovernmental organizations for the public consciousness against the nocuous and chronic effects of microplastic pollution. Apart from that, more scientific innovation should be encouraged which will facilitate to produce environment friendly derivatives instead of plastic materials (Figure 2).

Overall representation of sources and deleterious effects of microplastics on marine biota and control measures for this problem

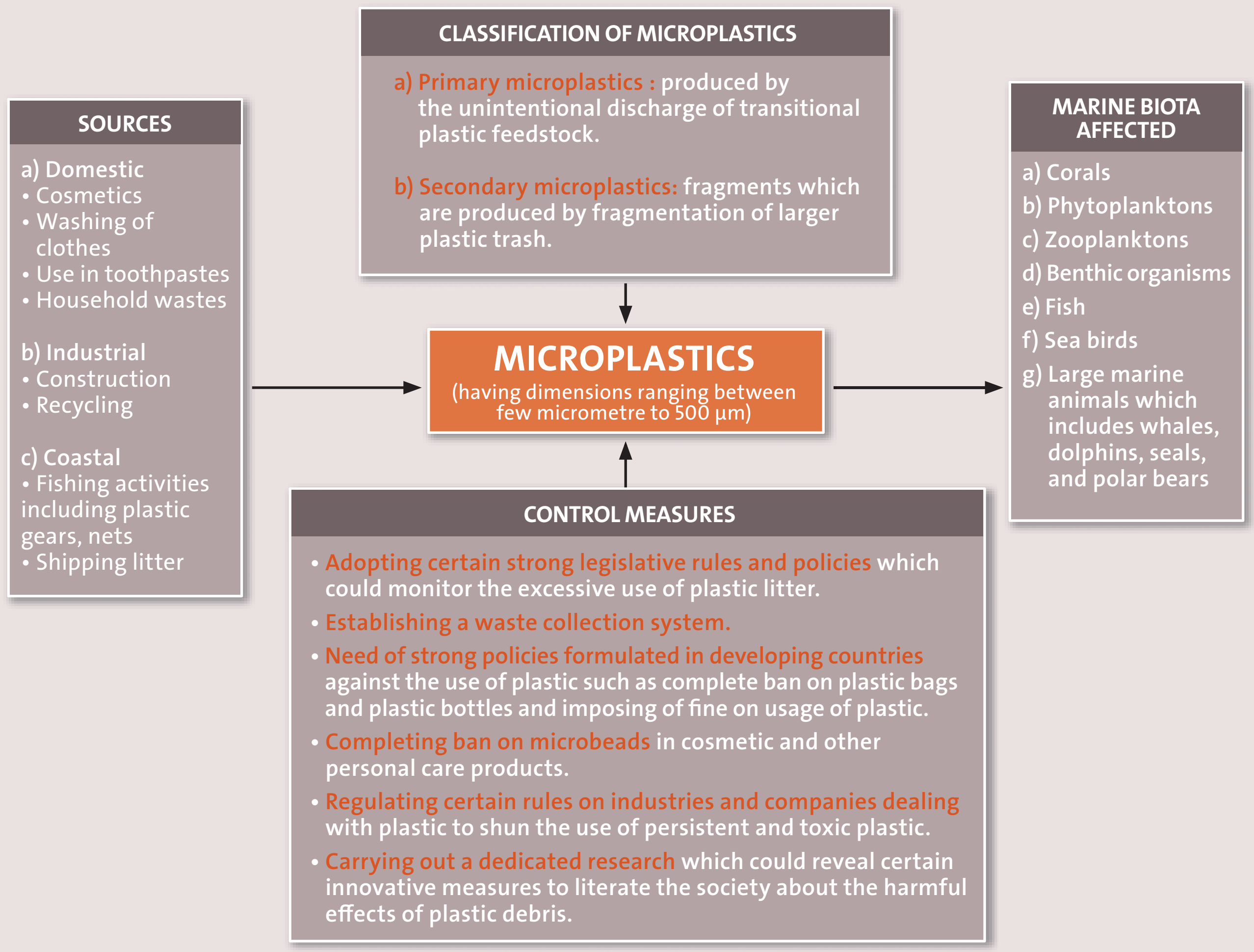

Figure 2

CONCLUSION

The problem of plastic pollution in the marine ecosystem is an issue of concern nowadays because of its deleterious effects on marine biota. Due to the size of microplastics, their bioaccumulation potential is very high. They are ingested by an array of marine habitants like corals, planktons, fish, seabirds and marine mammals and are transferred along the food chain. Also plastic polymers have different chemical additives and stabilizers due to which it absorbs various toxic contaminants and pollutants from the surrounding environment. Thus these harmful contaminants adhere to the microplastics which act as a vector. The problem of microplastics has been ignored for a long time and this threat has been recognized only recently. At present, drinking water, table salt and other daily used food items are contaminated with microplastics. There are various social active platforms such as *Plastic Pollution Coalitions, Plastics for change, Plastic Oceans, Surfers Against Sewage, Greenpeace, By the Ocean We Unite, One More Generation, One Green Planet, Surf Rider Foundation, Earth Guardians* who are working on the issue of microplastic pollution and contributing substantially. The adverse effects of microplastics pollution in the marine environment spans from molecular level of organism to its physiological actions and include poor health of organisms and poor economic services. Thus immediate actions are urgently required against the unnecessary use of plastics and its products. Strict measures must be enforced at national and international levels against the use of plastics. New scientific studies are required to elucidate various factors which influence the presence of microplastics in marine ecosystem and its biological impacts on marine biota. New research methodologies must be developed for conservation management and supporting different educational programmes for the protection of ecosystem against these harmful polymers. The very urgent call in this field is to spread awareness among the general public regarding the nocuous effects of microplastics. This would stimulate various innovations to reduce the utilization and consumption of plastic and its products. To minimize the plastic input into the ecosystem the most important approach is to collect and reuse of plastic fragments. To avoid future threat, the best solution is to stop producing it further and find out the alternative of plastic products.

ACKNOWLEDGMENTS

Financial support for this work was provided to SS by SERB-DST, Govt. of India (PDF/2016/000818).

Compliance with Ethical Standards

Conflict of interest: Authors declare no conflict of interests

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MICROPLASTICS IN THE OCEANS: THE SOLUTIONS LIE ON LAND

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The Tara under sail power
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Tara Expeditions Foundation is a recognized public interest non-profit organization that has been working for 15 years to improve understanding of the oceans and promote their protection.

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KEYWORDS

- MICROPLASTICS
- OCEANS
- POLLUTION
- PLASTIC BAG
- MEDITERRANEAN

There are 5,250 billion[1] plastic particles floating on the surface on the world's seas and oceans, equivalent to 268,940 metric tons of waste. These fragments move with the currents before washing up on beaches, islands, coral atolls or one of the five great ocean gyres. As early as 2010, Tara Expeditions Foundation was one of the first bodies to undertake a scientific examination of microplastic pollution in the oceans, an issue previously subject to very limited scientific study. Tara wanted to use its ocean study programs to understand the impact of this pollution on marine life. In 2014, Tara conducted a seven-month expedition in the Mediterranean Sea to improve understanding of the consequences in a semi-enclosed sea. The expedition highlighted the fact that microplastics are heavily colonized by bacteria. Research into sea-borne plastic has since become an integral part of Tara's work. Excessive consumption of plastics, and the waste this generates, has a massive impact on the natural world and the marine environment in particular. In this knowledge, Tara conducts scientific studies to improve our understanding of the risks to humans and marine ecosystems. Faced with the gravity of the situation Tara is convinced that, if we are to avoid plastics ending up in the oceans, the solutions lie on land. This involves a collective re-engineering of how we produce and consume, for example banning single-use plastic bags.

INTRODUCTION

MICROPLASTICS: WHAT ARE WE TALKING ABOUT HERE?

The vast majority of plastic fragments in the seas are microplastics. These are pieces of debris smaller than 5 mm in size and very varied in dimensions, color, shape, density and chemical composition. Although some fragments do wash up on beaches and coastlines, the vast majority of microplastics stay far out at sea before eventually breaking up, a process that can take anywhere from 100 to 1,000 years.

We distinguish between primary microplastics, which are directly introduced into the environment in the form of small plastic particles (microbeads in cosmetics, textile fragments, fragments from vehicle tires, etc.), and secondary microplastics that result mainly from the break-up of large pieces of plastic waste into smaller plastic fragments once exposed to the marine environment. Single-use plastic bags are among the largest sources as they break up very easily under the action of sun and seawater.

1 Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347, 768–771. doi:10.1126/science.1260352

Recent research[1] estimates that there are 5,250 billion plastic particles floating on the surface on the world's seas and oceans, equivalent to 268,940 metric tons of waste. These fragments move with the currents before washing up on beaches, islands and coral atolls. Other fragments end up in one of the five giant ocean gyres, the largest and best-known being the North Pacific Gyre. And if the impact of this ever-growing pollution remains little understood in terms of biodiversity and human health, the economic costs are considerable. Recent studies suggest that the financial damage caused by plastics in marine ecosystems amounts to around $13 billion annually. The negative impacts are felt by fishing industries and boaters as well as the islands and coastal towns that rely on tourist income.

I - MICROPLASTICS IN THE OCEANS: AN UNDER-STUDIED FIELD

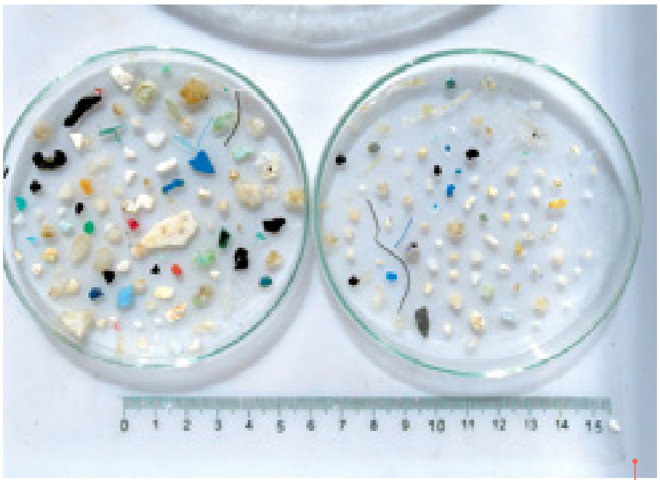
Plastics are materials with immense potential. Plastics are cheap to make and have ideal properties: lightweight, strong, resistant, flexible or rigid, opaque or transparent, they adapt to every imaginable type of product. They were quickly taken up by industries worldwide. Since modern plastics were first invented in the early 20th century, production and use of plastics has grown exponentially in all fields, from construction to vehicles and electronics, to the current position where annual production amounts to around 300 million metric tons. Designed to last, most plastics are nonetheless produced for applications with short lifespans: almost half will end up as packaging to be thrown away immediately after purchase. Their uses might be ephemeral but their presence in the environment is anything but transitory: once used, if they are not collected and recycled, plastics systematically end their lives abandoned in nature, particularly the sea.

WHY IS IT SO IMPORTANT TO STUDY THIS? TARA FOUNDATION AND ITS PROGRAM ON PLASTICS IN THE SEAS

Tara Foundation is France's only recognized public interest non-profit organization focused specifically on the oceans.

Using a variety of advanced technologies, genetics, genomics, the latest advances in sequencing and Big Data, Tara is helping to foster the emergence of innovative and groundbreaking science that helps improve understanding of the oceans and the impact of climate change and environmental degradation on this ecosystem of vital importance for humanity's future. As a fully operational floating laboratory, Tara's schooner has already completed 11 major expeditions to all the world's oceans, collaborating with many top-flight international research institutions including CNRS, CEA, ENS, EMBL, MIT and NASA.

1 Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347, 768–771. doi:10.1126/science.1260352



Microplastics sample taken from the Great Pacific Garbage Patch at 34°42'210 N - 142°21'004 W.
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The foundation is also fully committed to open science and citizen science, sharing all its data and scientific protocols. Tara is convinced that sharing knowledge and transcending traditional frontiers is the best way to protect and manage the oceans. It makes all data acquired during its expeditions – currently the world's largest multi-disciplinary ocean database – available to scientists worldwide.

All its missions fully support Agenda 2030's Sustainable Development Goal 14, "Conserve and sustainably use the oceans, seas and marine resources", something that the foundation is deeply engaged with at international and national levels. With observer status at the UN since 2015, it plays an active part in various U.N. commissions and conferences, providing its scientific expertise to multilateral negotiations on the high seas, climate change and reducing pollution from plastics. It is also a member, and currently chair, of Océan et Climat, a French umbrella body whose 80 or so members include research institutions and actors from civil society and business.

Tara's program on plastics in the sea concentrates on research into microplastics, with a split focus between the Mediterranean and the world's great oceans via our program of expeditions. The Tara Méditerranée expedition was designed to grow knowledge about the impacts of plastics on the Mediterranean ecosystem. The mission quantified numbers of plastic fragments, their size and mass. It also identified the types of plastics found in the sea. As yet unexplored microscopic ecosystems of bacteria, viruses, micro-algae and micro-predators form on the surface of these plastic fragments, which raises the question of their probable entry into the food chain, an issue previously almost completely ignored in the Mediterranean.

Beyond the scientific aspects, the issue of marine plastics is also a key vector driving awareness of the oceans. Press and social media are awash with pictures of floating plastic bags, bottles and other debris, triggering worldwide indignation and concern. Extensive media interest is

Justine Jacquin sorts samples, Jonathan Lancelot and Nils Haentjens haul in the Manta net.
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certainly beneficial but it is too often overly hasty, peddling unverified information and figures. Tara's preference is to work from robust scientific data, respecting the science and not scaremongering about the potential dangers of marine plastics.

The oceans are under pressure, but unsettling images and alarmist statements often do nothing to further the search for actionable solutions with the various stakeholders. We sincerely believe that solutions are possible, no matter how bad things may seem, but these solutions are to be found on land, in a circular economy with recycling, reuse of resources and transition to environmentally friendly and non-polluting packaging.

II - THE MEDITERRANEAN: ONE EXAMPLE OF THE IMPACT OF MARINE MICROPLASTICS

The Mediterranean Sea is one of the world's regions most impacted by marine pollution. Some 700 tonnes of waste pour into it daily. Being semi-enclosed, the Mediterranean is even more vulnerable to plastic pollution than the ocean; its water has a 90-year renewal period and plastics persist for periods in excess of 100 years. There are currently 1,000 to 3,000 tonnes of plastics floating on its surface: fragments from bottles, bags, packaging, fishing lines and so on, mostly accumulating from large coastal towns and cities, regions with significant tourist activities, and open-air waste dumps.

The majority of pollution in the Mediterranean is not visible floating waste (macroplastics) but the 250 billion fragments of microplastics it contains.

This is a problem exacerbated by other factors: densely populated coastlines, highly developed tourism, the passage of 30% of the world's maritime traffic, and additional waste inflows from rivers and highly built-up zones. Some 95% of marine waste in the Mediterranean is plastic, leading some experts to label it the world's sixth major marine waste accumulation zone, after the five ocean gyres.

Invisible pollution has numerous impacts and consequences are little understood:

- Microplastics attract and accumulate contaminants already present in the water, such as chemicals and fertilizers.
- Their small size means there is a real risk that filtering animals, such as fishes and whales, will confuse microplastics with plankton.

- The role waste plastic may play in the emergence of human health problems remains uncertain because of a lack of understanding of:
  - levels of exposure to contaminants caused by waste plastic;
  - mechanisms by which chemicals absorbed by plastics are then transferred to humans and marine species.

TARA MEDITERRANEAN EXPEDITION

In 2014, with support from the Veolia Foundation, Tara led a unique seven-month expedition around the Mediterranean basin specifically to study microplastics. The expedition took 2,000 samples from 350 different areas near to coasts, cities, river mouths and in ports. The data gathered, representing 75,000 plastic particles, is the largest collection of microplastics ever gathered from the Mediterranean.

These data are currently being analyzed by a number of laboratories, including Villefranche-sur-Mer, Banyuls and Université Bretagne Sud. Since 2015 these labs have also been monitoring the most polluted part of the Ligurian Sea.

After the Tara Mediterranean Expedition returned to shore, Tara teamed up with other partners involved with the Mediterranean as part of Beyond Plastic Med, a body seeking to find actionable solutions for reducing plastic pollution in the Mediterranean rather than just recording the facts. Members of this initiative are Tara Foundation, the Prince Albert II of Monaco Foundation, the Veolia Foundation, Surfrider Foundation, the International Union for Conservation of Nature, and the Mava Foundation. Since its establishment it has run a number of initiatives including workshops with the private sector, awareness-raising films and funding for grassroots civil society projects around the Mediterranean.

We sincerely believe that solutions are possible, no matter how bad things may seem, but these solutions are to be found on land, in a circular economy with recycling, reuse of resources and transition to environmentally friendly and non-polluting packaging.

At the same time, scientific institutions involved in the Tara Mediterranean Expedition continued their research into microplastics and are in the process of consolidating their initial results, with publication expected within the coming two years. News of a first discovery, published in February 2018, concerned bacterial colonization of microplastic fragments. Tara's schooner continued to make marine studies and analyze samples collected from the Arctic region, and it is currently applying new protocols for collecting samples from the Pacific.

Today, faced with the enormity of the challenge, it is vital to support research designed to produce actionable results capable of driving changes in public policy and transition to more environmentally friendly practices.

To this end, Tara has designed its marine plastics program so that it conducts scientific studies to improve understanding of both the origins and routes to the sea followed by microplastics, of how it disperses, its toxicity and impacts on marine biodiversity and the food chain. We thereby hope to further our understanding of the risks to humans and the marine ecosystem.

FOCUS: MICROPLASTICS IN THE MEDITERRANEAN, PATHWAYS FOR INVASIVE SPECIES

In 2014, after traveling the Mediterranean for a seven-month expedition aboard the Tara's schooner, the conclusion was stark: whether near to the coast or out at sea, plastics were everywhere; 100% of the Mediterranean is polluted with plastics. More alarming still, the concentration of microplastics (< 5 mm) in some locations is greater than in the Great Pacific Garbage Patch, the so-called seventh continent of plastic, and in numbers of a similar order to plankton, which forms the base of the food chain.

In March 2018, the Banyuls Oceanic Observatory team led by Jean-François Ghiglione published an article in *Environmental Pollution* demonstrating that microplastics are heavily colonized by bacteria. "Bacteria love living on plastics. We find them in very large concentrations, with great biodiversity, greater still than in an equivalent volume of seawater", says the CNRS researcher.

The researchers found colonies of unexpected types of bacteria, including certain cyanobacteria typically found in sediment layers that were found to be extremely abundant on plastics floating on the surface. "Dispersion of invasive species is one of the big problems with plastic pollution, as these attach themselves to what are effectively artificial rafts and can thus travel great distances. Such species are capable of effecting lasting change to ecosystems they colonize", he warns.

Tara Mediterranée plastics -©N.Sardet/TaraExpeditions

The team joined the Tara Pacific expedition in June 2018 to take samples from the plastic gyre and continue their investigation into the lives of microorganisms that colonize the new plastic ecosystems known as the plastisphere. Research into interactions between microplastics and the marine microbiota are important if we are to gain an understanding of how and under what conditions certain bacteria are able to degrade, or even digest, plastics, as recent laboratory studies have shown.

III– THE SOLUTIONS LIE ON LAND!

OUR FUTURE: AN OCEAN OF PLASTIC?

"Plastics comprise the vast majority of the 10 to 20 million tonnes of waste influx of all types into the ocean every year. Almost all objects floating on the surface are plastics. Although some debris does come from marine activities, on average 70% to 80% of waste in the sea comes from land, most of it carried by rivers".[2] Excessive consumption of plastics and the waste that this generates has a massive impact on the natural world, and the marine environment in particular. Environmental damage caused by waste plastic to marine ecosystems in terms of species mortality, habitat destruction, chemical contamination, propagation of invasive species and financial losses to fisheries and tourism may represent over $13 billion per year.[3] "Plastics undoubtedly play a crucial role in modern life, but the environmental impacts of the way we use them cannot be ignored", says Achim Steiner, former Executive Director of the United Nations Environment Program. It is urgent to act now for the Mediterranean, which is subject to enormous strains caused by human activities.

We need to re-examine our lifestyles if plastics are to stop taking over the oceans.

WASTE PLASTIC MUST NO LONGER END ITS LIFE IN THE SEA: THE SOLUTIONS LIE ON LAND

Faced with this alarming situation, many people's first reaction is to turn to technology in the hope of finding a solution that will clear floating plastics from the planet's seas and oceans. But the oceans are vast and the amount of debris is growing all the time, and the emergence of microplastics makes it harder and harder to collect. Although clean-ups remain indispensable, focusing on them is to attack the consequences of the problem but ignore the causes. We have to act upstream. Only by preventing waste from entering the sea can we hope to protect and restore the oceans for the long term. Despite the seeming simplicity of this solution and the strategy it implies – reducing the amount of plastic produced and persuading people not to litter – it is by no means easy to put in place, being predicated on fundamental changes in behavior by plastics manufacturers as well as consumers. We need to re-examine our lifestyles if plastics are to stop taking over the oceans.

CHANGE CONSUMER BEHAVIOR: REDUCE, REUSE, RECYCLE

Not many people have any idea of the amount of waste that they produce simply as a result of their day-to-day activities. Awareness-raising and a conscious effort to change habits are needed if the impact of plastics is to be minimized: we need to move toward less waste and more reuse and recycling. Consumers clearly play a vital role. Buying responsibly is one way to prevent the production of waste plastic: opting for products with little or no packaging, choosing products that are long-lasting and reusable rather than highly waste-generating disposable products such as plastic plates and glasses, disposable razors, etc., and refusing plastic bags from shops. Reusing items instead of throwing them away can give objects a new life. Maintain and repair, sell or give away items that are no longer used, reuse packaging, containers and spare parts, return bottles for a deposit where possible – these are all simple ways for people to reduce their waste footprint. Lastly, consumers must also take responsibility for sorting their waste and making sure that end-of-life products are sent for appropriate recycling, where this is available. Awareness-raising and the presence of appropriate infrastructure are both critical if changes in behavior of this type are to occur. And this is about more than just plastics – the way that we think of the sea must change too. Considerable education is needed to stop people thinking of the seas as a vast reservoir where waste can be dumped without any consequences.

SINGLE-USE PLASTICS: ENCOURAGING PROGRESS

Plastic bags were for a long time features of our daily lives without us knowing anything of the consequences. But scientists are increasingly highlighting the alarming impact they have on the seas. Tara is now lobbying governments and multilateral bodies to take concrete steps, given the scale of plastic pollution observed during its expeditions and in the light of France's decision to ban lightweight plastic bags as of 2016. A worldwide ban on single-use plastics, which cause such harm to our environment, is vital for the health of humanity and the seas.

Mediterranean basin countries including Morocco and Monaco have announced bans on single-use bags but more progress is needed among the region's big polluters, such as Egypt and Lebanon, where waste management remains inadequate. Faced with this scourge, it is important to remember that solutions always inevitably involve creating suitable, which means costly, infrastructure such as wastewater treatment plants and recycling facilities. These investments are needed more than ever in countries of the South, all the more so as the oceans know no frontiers and marine currents quickly circulate plastic particles across the entire Mediterranean basin.

2 UNEP, Achin Steiner, 2014

3 http://www.unep.org/newscentre/Default.aspx?DocumentID=2791&ArticleID=10903&l=en

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Billions of thin plastic bags continue to be handed out every year in France at tills or when buying fruit and vegetables, and most of them are discarded after a single use. It takes 100 to 500 years for bags like this to degrade in the environment. Being extremely thin, they are of no use to monetized recycling systems, unlike bottles and rigid containers that can be sold by weight. They are easily carried by the wind and whether or not carefully deposited in a waste bin, waste plant or deliberately thrown on the ground, the majority of them will end their journeys in the sea. Once in the sea, their impact is devastating. Carried over great distances, they damage the seabed and endanger animals that ingest them, become entangled in them or contaminated by the toxic substances they give off. Under the action of sea currents the bags are fragmented into microparticles that disperse throughout the environment. Absorbed by marine organisms the microparticles move up the food chain, ultimately ending up on our plates. Single-use plastic bags are a potential threat to human health and represent a not inconsiderable cost to society as a whole. Every activity in some way related to the sea or coast – fisheries, fish farming, leisure activities and tourism – is harmed by their presence.

CONCLUSION

There is no golden bullet – genuine solutions will arise from concerted action by civil society, policymakers and business.

Faced with the sheer scale of the task of tackling ocean pollution, some people suggest miracle solutions for a clean-up of the seas, others propose developing enzymes that will eat the plastic, while others still attempt to build boats that will clean the oceans. Although it would of course be wrong to exclude explorations of possible technological solutions for the future, we believe that achievable solutions exist already, and that most of them are to be found on land, focused on prevention and proper processing of waste and water.

To transform habits so that every household produces less waste, and people no longer automatically throw things away, will require an enormous effort to educate people, be they inhabitants of coastal countries or one of the many millions of tourists who flock each year to the Mediterranean or the isles of the Pacific. Of course, citizens are not the only ones at fault here. Prevention of plastic waste also has to happen upstream, among manufacturers and retailers, long before products reach consumers. Attempts to persuade plastics manufacturers to stop producing the material are doomed to fail. More responsible forms of manufacturing are the key to reducing the amount of waste generated. Business can alter the paradigm by reducing the amount of packaging and designing long-lasting products that are easy to maintain and repair, able to be reused or recycled.

According to Achim Steiner, “Reducing, recycling and redesigning products that use plastics can bring multiple green economy benefits – from reducing economic damage to marine ecosystems and the tourism and fisheries industries, vital for many developing countries, to bringing savings and opportunities for innovation to companies while reducing reputational risks”. At the same time, replacement with alternative materials and better management of plastics to encourage recycling and reuse would deliver significant savings to manufacturers of retail goods. Annual savings are currently estimated at some $4 billion and this amount can only increase.

THE CHALLENGES OF MEASURING PLASTIC POLLUTION

Guillaume Billard and Julien Boucher
Environmental Action (EA)

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Guillaume Billard recently graduated from Newcastle University (UK) with an MSc in International Marine Environmental Consultancy.

Since 2014, the EA team has been working towards better integration of plastic pollution in footprinting and Life Cycle Assessment methodologies, and hopes to contribute to "closing the plastic tap".

KEYWORDS

- PLASTIC FOOTPRINT
- MARINE POLLUTION
- LIFE CYCLE ASSESSMENT
- ECO-DESIGN

Plastic is a single word for a multifaceted reality, encompassing a wide variety of polymers and additives with different chemical and physical properties. The end products range from single-use plastic bags, food wraps and plastic bottles, to fishing lines, buoys, and synthetic fibres used in the clothing or fishing industries.

As the use of plastic is pervasive, so is plastic pollution. An estimated 10 million tonnes of plastic leaks into the ocean each year, causing an unprecedented environmental crisis. Measuring or forecasting this issue is a complex and challenging task, due to technical limitations and uncoordinated assessment campaigns. Acting to tackle this issue requires adequate metrics to guide and prioritise action at different levels, ranging from sound product design and efficient regional infrastructure, to adequate policies and enforcement.

INTRODUCTION

It is not only our feet which leave a footprint on sandy beaches – our heavy reliance on plastic materials is creating a visible yet pervasive "plastic footprint" in the environment. This increasing usage is generating considerable amounts of litter, ultimately reaching the marine environment. Considered a major threat to both wildlife and human wellbeing, plastic pollution is now ubiquitous in the World ocean (UN Environment, 2018), causing an unprecedented environmental crisis, with an estimated 10 million tonnes of litter leaking into the marine environment every year (Boucher and Friot, 2017).

Subject, among other parameters, to currents and wave action, plastics are likely to accumulate in different compartments of the oceans (e.g. surface, sediments), and break down into submillimetre-sized debris which can ultimately be ingested by marine life.

This rise in plastic consumption is not surprising, as these materials provide many benefits to society through their malleability, durability and lightness, together with low production costs. For many applications, plastics can even offer lower carbon footprint alternatives compared to other materials (Boucher and Friot, 2017).

Since the 1950s, yearly production of plastics has risen from close to zero to above 335 million tonnes in 2017, with an annual increase forecast at 4% for the coming years (Geyer, Jambeck and Law, 2017; PlasticsEurope, 2017). This plastic crisis stresses the need to use better forecasting metrics to manage environmental trade-offs and to guide industries and governments towards sound product design and waste management infrastructure.

At present, current Life Cycle Assessment (LCA) and footprinting methods used to guide companies and designers still neglect plastic pollution.

This review firstly aims to give an overall description of the plastic pollution issue, with a focus on the quantities of plastic flowing into oceans (i.e. the "leakage"). Secondly, it will further discuss current knowledge gaps and challenges underlying both plastic assessment at sea and forecasting plastic leakage (i.e. "footprinting"). Lastly, the conclusion will stress on the need to act now and, concomitantly, on both action and developing these metrics.

CURRENT KNOWLEDGE STATUS ON PLASTIC POLLUTION

HOW MUCH PLASTIC IS LEAKING?

Several studies have inventoried and quantified different sources of plastic leakage either at country level or globally (Lassen et al. 2015; Essel et al. 2015; Magnusson et al. 2016). We call leakage the quantity of plastic flowing into waterways and, ultimately, into the oceans. Global plastic leakage is estimated in the order of 10 million tonnes per year (Mt/y), with different authors presenting yearly values of:

- 4.8 Mt/y to 12.7 Mt/y (Jambeck et al. 2015)
- 8.28 Mt/y (UN Environment, 2018)
- 12.2 Mt/y (EUNOMIA, 2016)
- 10 Mt/y (Boucher and Friot, 2017).

Plastics can be encountered in two forms: large plastic wastes called macroplastics, which usually enter the marine environment in their manufactured sizes, and small plastic particulates below 5 mm in size called microplastics. The latter break down into two types:

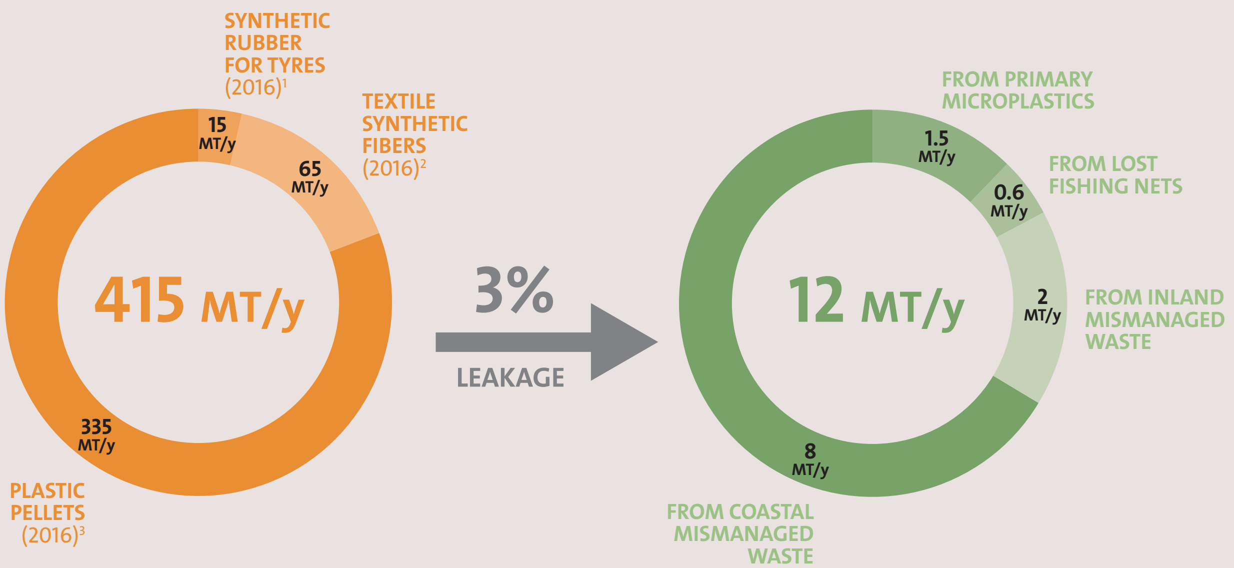
- **primary microplastics** are directly released into the environment in the form of small particles. They can be a voluntary addition to products such as scrubbing agents in toiletries and cosmetics (e.g. shower gels). They can also originate from the abrasion of large plastic objects during manufacturing, use or maintenance, such as the erosion of tyres when driving or the abrasion of synthetic textiles during washing;
- **secondary microplastics** originate from the degradation of larger plastic items into smaller plastic fragments once exposed to the marine environment. This happens through photodegradation and other weathering processes of mismanaged waste such as discarded plastic bags or from unintentional losses such as fishing nets.

WHAT IS THE CONTRIBUTION OF THE DIFFERENT SOURCES?

This question remains a subject of debate. Figure 1 shows the main sources together with their most frequently cited quantities (green pie chart), in comparison to the global amounts of plastic produced (orange pie chart). This comparison sheds light on a relative leakage rate of 3%, meaning that 3% of all plastic put on the market will ultimately end up in the ocean.

A higher estimate has been put forward by the World Economic Forum, with an estimated 32% of single-use packaging escaping collection systems (WEF, 2016).

Yearly plastic leakage into the marine environment based on worldwide plastic pollution data



1 https://www.statista.com/statistics/271651/global-production-of-the-chemical-fiber-industry/ & http://www.rubberstudy.com/documents/WebSiteData_Feb2018.pdf
2 https://www.statista.com/statistics/271651/global-production-of-the-chemical-fiber-industry/
3 https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf

Source: Boucher et al. in press; IUCN – The marine plastic footprint

Figure 1

The section below describes leakage from four main sources, estimating the quantities flowing into the marine environment as reported in the literature:

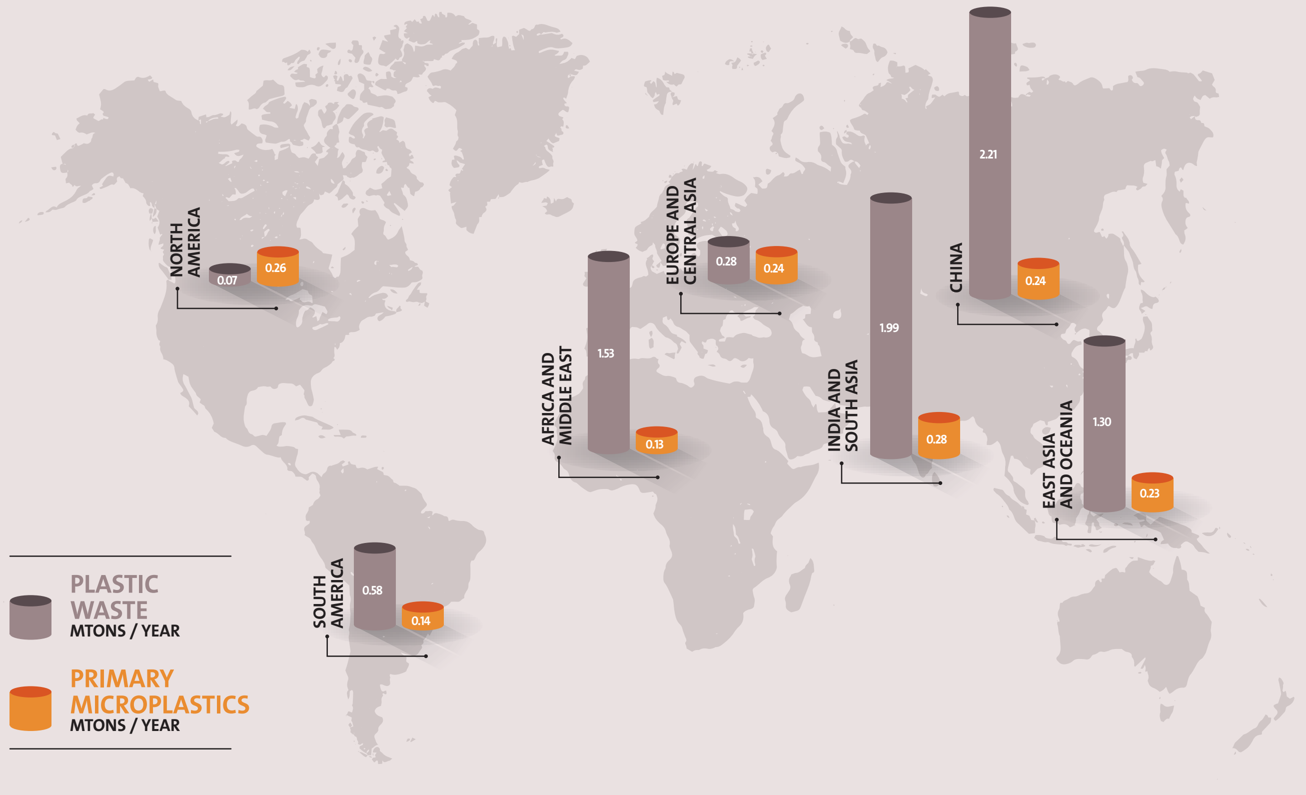
i. **Coastal Mismanaged Plastic Waste (MPW): 8 Mt/y**
The most commonly cited orders of magnitude were published by Jambeck et al. in 2015. This research focused on the amount of mismanaged plastic waste likely to be generated by the coastal population of 192 countries living in a 50 km fringe from the shore. Calculations were based on the mass of waste generated per capita annually, the percentage of plastic materials in the waste and the percentage of mismanaged plastic waste likely to enter the oceans as debris (which includes the share of inadequately managed waste per country and a default global littering rate of 2%).
This research concluded that annual leakages of MPW into the marine environment range from 4.8 to 12.7 Mt/y. Additionally, other MPW estimations have been published, varying from 3.87 Mt/y (UN Environment, 2018) to 9 Mt/y (EUNOMIA, 2016) on their global plastic leakage estimate of 8.28 Mt/y and 12.2 Mt/y respectively.

ii. **Inland MPW: 2 Mt/y**
Contributions of rivers to global the leakage fluctuate depending on seasonality and geographical location. Globally, rivers would be responsible for plastic waste inputs ranging from 1.15 Mt/y to 2.41 Mt/y, with 67% of these emissions originating from Asia alone (Lebreton et al. 2017).
Interestingly, the above-mentioned study is supported by field measurements showing good correlation between population densities, waste management data and results from observational river studies.
In addition, another study estimated riverine inputs as ranging between 0.41 Mt/y and 4 Mt/y (Schmidt, Krauth and Wagner, 2017). Discrepancies between the two studies are due to different parameters used, such as the number of coastal countries considered.

iii. **Lost fishing gear: 0.6 Mt/y**
The fishing and aquaculture sectors emit large quantities of litter (e.g. derelict gear), including 0.6 Mt of microplastics per year for the fishing industry (Boucher and Friot, 2017). For example, field studies report a prevalence of blue fibres (nylon) specific to fishing devices. Other orders of magnitude have been published, with, for example, a loss

Global releases of primary microplastics and plastic waste into the World ocean

Comparison with plastics originating from mismanaged wastes



Source: Boucher, J. and Friot D. 2017

Figure 2

rate of derelict fishing gear of 1.15 Mt/y (EUNOMIA, 2016). The sources here are very scarce and the precise contribution is highly unreliable. In addition, shipping litter thrown overboard, which is supposedly prohibited, also contributes to overall plastic pollution with estimates of 600 kt/y (EUNOMIA, 2016).

iv. **Primary microplastics: 1.5 Mt/y**
In this study, we consider that 1.5 Mt/y enters the marine environment in the form of primary microplastics. However, many sources differ on the contribution of primary microplastics to the overall plastic loss. Primary microplastics are estimated at:
- 3.01 Mt on a total plastic loss of 8.28 Mt/y (UN Environment, 2018)
- 1.5 Mt/y on a total plastic loss of 8 Mt/y (Boucher et Friot, 2017)
- 0.95 Mt on a total plastic loss of 12.2 Mt/y (EUNOMIA, 2016).

In percentage share, it equates to approximately 36%, 15% and 8% of global plastic leakage (UN Environment, 2018; Boucher and Friot, 2017; EUNOMIA, 2016). Per sources, leakages due to tyre abrasion would equate to 1,400 / 420 / 270 kt/y (UN Environment, 2018; Boucher and Friot, 2017; EUNOMIA, 2016). Road marking leakages: 590 / 105 / 80 kt/y and washed out microfibres estimated at 260 / 525 / 190 kt/y according to the same sources.

Although these estimates are still a subject of debate, there is a consensus on the fact that they are mainly caused by the leakage, dependent on regional conditions and archetypes. Leakage of macroplastics from mismanaged waste is dominant in coastal countries, especially those with less adapted waste management facilities (Boucher and Friot, 2017). Figure 2 below the contribution of primary microplastics and mismanaged waste to global plastic pollution.

These regional differences are the result of varied patterns and pathways that depend on local characteristics, such as population densities, GDP, cultural habits and the effectiveness of local infrastructure to retain waste, which concords with the IPAT theory (Impact = population * affluence * technology) (Ehrlich and Holdren, 1971).

These regional and sectoral differences are further illustrated in Figure 3 for different microplastic sources. Shaping actions requires defining emissions hotspots, which urgently needs the development of an industry-specific and regionalised plastic footprint methodology.

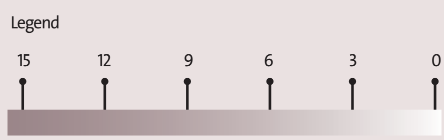
Such footprinting approaches could be based on measuring quantities as well as integrating the assessment of the resulting environmental and human health impacts:

i. *Macro-sized debris*: affects both wildlife and human wellbeing. Large items can be ingested by marine megafauna (de Stephanis et al. 2013), which can ultimately lead to death by starvation. Entanglement in derelict fishing gear ("ghost fishing") is also a growing concern. Plastic pollution economically affects human coastal communities, with approximately €18 million per year being spent on beach litter removal in the UK alone (Lee, 2015.)

Global releases (%) to the World oceans by geographical area and sources

Key sources among regions (total amount to 100%)

INDIA AND SOUTH ASIA	15.9	1.1	0.3	0.1	0.8	0
NORTH AMERICA	2.6	11.5	1.9	1	0.1	0.1
EUROPE AND CENTRAL ASIA	4	8.6	2.4	0.6	0.2	0.1
CHINA	10.3	2.5	1.3	1.2	0.5	0
EAST ASIA AND OCEANIA	6.3	5.3	1.6	1.5	0.3	0
SOUTH AMERICA	2.9	5.1	0.9	0	0.2	0
AFRICA AND MIDDLE EAST	4	3.2	0.6	0.4	0.5	0



Source: Boucher, J. and Friot D. 2017

Figure 3

ii. *Meso/micro-sized debris*: plastic debris have also been found encrusted with organisms such as bryozoans (moss animals) or algae, creating a transport vector for invasive species (Gregory, 2009). This transport is a considerable threat to areas where endemism is important, such as isolated sub-Antarctic islands. Additionally, ecosystem impacts are suspected through the accumulation of microplastics in the food chain, which could potentially transfer to humans via direct consumption of seafood. It is estimated a 50-fold increase in surface microplastic concentrations by 2100 (from 0.2-0.9 particles m^3 in 2010 to 9.6-48.8 particles m^3 predicted in 2100) (Everaert et al. 2018). However, no direct effects linked to free-floating microplastics are expected (excluding some toxical pollutants adsorbed at the surface of these particles – e.g. some pesticides) in normal conditions, though areas with higher concentrations than average could potentially be at risk (Everaert et al. 2018). A precise estimation of these potential and different impacts of plastic debris will still require further years of research.

A comprehensive assessment of these impacts within a life-cycle based framework would make it possible to (i) compare the impact of different plastic leakages (e.g. different polymers or different object shapes), and (ii) allow for analysis of trade-offs between plastic-related impacts and other potentially severe environmental burdens.

Although the theoretical framework and impact pathways seem quite clear, supporting data (i.e. the fate factors, characterisation factors and ecotoxicological data) are not available yet. As a result of this knowledge gap, a plastic leakage inventory indicator should be used to guide decision-making in the short term (FSLCI, 2018).

This first section has described the current knowledge status of plastic pollution in the marine environment, with the overarching aim of describing the main issues and findings. The following sections will provide an overview of the challenges surrounding the use of models for plastic leakage forecasting as well as the challenges for measuring plastic at sea.

THE CHALLENGES OF FORECASTING PLASTIC POLLUTION

Forecasting plastic pollution is a challenging endeavour. As seen above, at a global level, many uncertainties prevail, which explains the discrepancies in numbers. These uncertainties can either be structural (related to the understanding of the mechanisms and pathways of the leakage) or data related (related to the availability of reliable datasets, which are particularly difficult to obtain in certain countries).

Developing a more specific and actionable methodology requires overcoming some of these uncertainties. Listed in the sections below are the main challenges that have to be solved in order to yield a reliable forecasting footprint method.

An attempt of a plastic footprinting framework methodology is described in Figure 4, highlighting the different loss patterns and release pathways.

MODELLING THE LEAKAGE FROM MISMANAGED WASTE AND FROM LITTERING

Mismanaged waste is commonly defined as plastic waste managed in a way that might include some leakage into the marine environment. This includes waste entering non-sanitary landfills, dumpsites, or tipped/littered.

Current limitations of this approach can be stressed, such as:

i. Lack of a standardised formula or dataset to calculate mismanaged waste, thus different approaches yield different results.

ii. Littering estimations are by nature complex to produce; litter may be identified from municipality cleaning operators' statistics, but not for the fraction that "falls through the cracks" (i.e. the leakage). This fraction is by definition not measured, and very difficult to "guesstimate". A proxy of littering has been brought forward by Jambeck et al. (2015), applying 2% for all countries.

iii. Release rates from mismanaged waste are rarely based on evidence, thus mainly hypothetical. The release pathways are poorly understood and release rates therefore provide indications rather than estimations. These release rates are typically described as varying from 10% to 40% (Jambeck et al. 2015; UN Environment 2018) without presenting regional variations. Factors such as cultural behaviours (e.g. littering habits), climatic conditions (e.g. effect of rain or wind on dispersal of waste from dumpsites) and geographic specificities (e.g. distance to shore and waterways) are expected to have a significant influence.

These strong uncertainties in the model should not prevent stakeholders from adopting priority actions. Using circularity indicators may be a reasonable option in the short term, while awaiting the definition of models to refine leakage pathways.

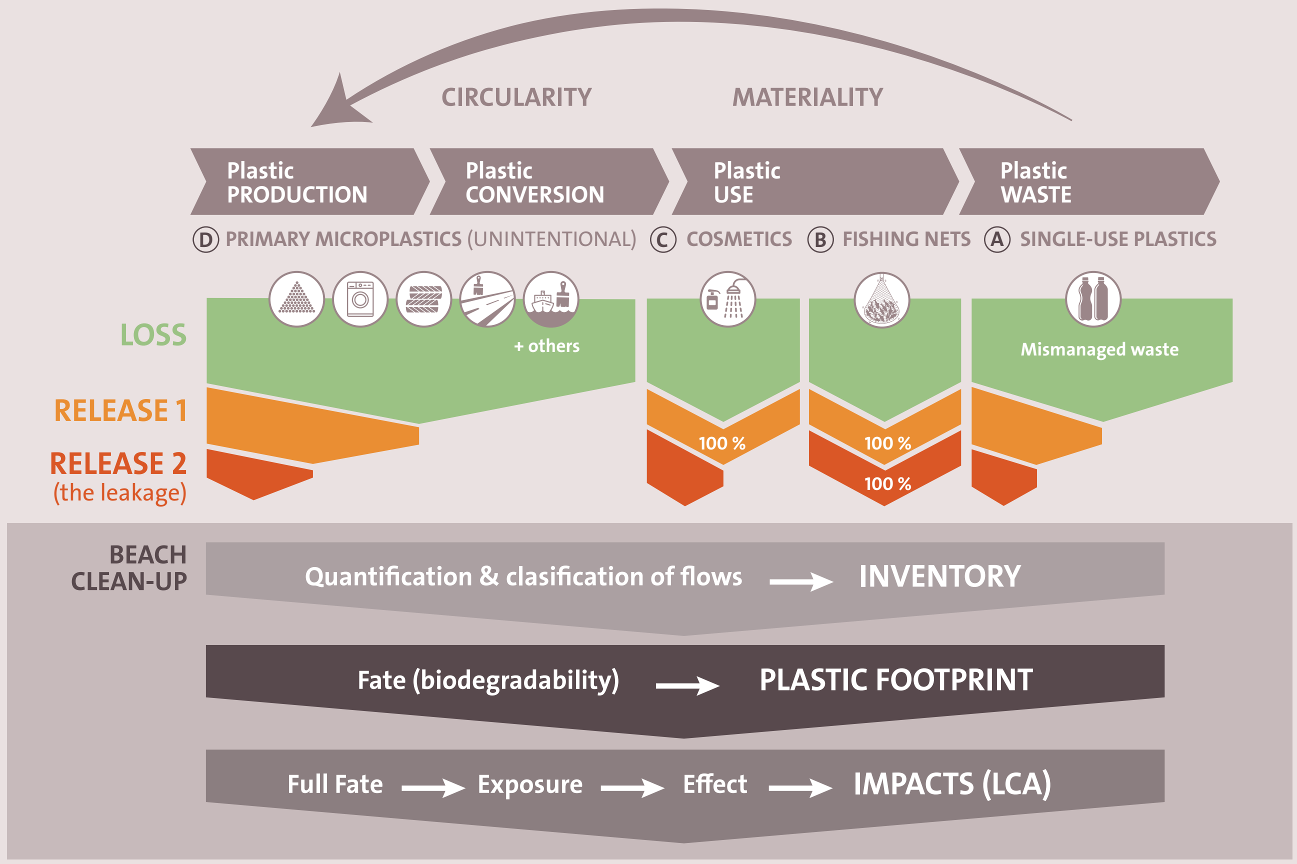
MICROPLASTIC SOURCES AND PATHWAYS

The leakage of primary microplastics is measured as a function of a loss rate and a release rate. The loss rate measures the quantity of plastics lost from a specific activity (e.g. driving, household washing). The release rate measures the fraction of this loss that ultimately reaches the ocean, i.e. is not captured in waste treatment plants or other infrastructure.

Loss rate estimates are now available in the literature, allowing for generic plastic footprint calculations. However, the drivers that make these rates fluctuate from low to high bonds remain unclear and hinder the use of such metrics for eco-design guidance.

The release rate is still bound to large uncertainties, as a result of the high complexity of the release pathways

Plastic footprint framework



Source: Boucher et al. in press; IUCN – The marine plastic footprint

Figure 4

(transfer into wastewater treatment plants, riverine transport, sedimentation). Tyre abrasion from motorised vehicles illustrates this well: lost rubber is estimated at 100 mg/km (1 g/10 km) for a passenger car (Kole et al. 2017). However, the fraction entering the marine environment remains unclear, possibly ranging from 2% to 44% according to different sources, with very few empirical studies measuring these releases in the environment (Boucher and Friot, 2017; Wagner et al. 2018; Unice et al. 2018).

THE FATE AND IMPACTS QUESTION

Fate modelling seems to be the first step in order to move towards impact assessment. Key questions need to be answered such as the degradation rate for different polymers in the marine environment, the rate of fragmentation from macro- to secondary microplastic, and duration of potential exposition to organisms. As the water column is stratified, a better understanding of the behaviour of debris inside the different layers of the sea is also required.

THE CHALLENGES OF MEASURING PLASTIC POLLUTION IN THE FIELD

Efficient top-down forecasting methods require some level of validation from field studies. However, comparing modelling and field approaches currently show questionable results. For example, 250,000 to 300,000 kt of plastic debris are reported as floating in the World Ocean (Eriksen et al. 2014; van Sebille et al. 2015).

This quantity is almost two orders of magnitude below the predictions of annual inputs based on modelled results (4-12 Mt, Jambeck et al. 2015). There is a debate in the scientific community regarding the spatial distribution and fate of plastics in the water column. It appears unclear as to whether plastics sink and hence accumulate in the deep-sea (thus not measured by surface sampling, Woodall et al. 2014; Koelmans et al. 2017) and/or may be accumulated in the food web or oscillating in the water column (Kooi et al. 2017).

Another hypothesis to bear in mind is that contemporary sampling methods are possibly not suitable for the detection of very small particles and correction models are rarely implemented.

i. Some studies focusing on surface quantification do not apply correction models when sampling in windy conditions. Concentrations can be largely underestimated due to wind and wave events. This is a major drawback in plastic pollution assessments as it has been shown that plastic (mainly micro-mesoplastic) concentrations could be 2.5 times higher when wind correction models are applied in > 8 knots conditions (Kukulka et al. 2012).

ii. When sampling surface debris, there is a tendency in the literature to provide metric results in average particles by surface area (items km^{-2}) and total particles counted. The weight of debris is rarely provided as additional information.

iii. Sampling methodologies (towing time and speed, net dimensions and mesh sizes) significantly fluctuate between studies, influencing the catchability of plastics. There is a lack of a standardised approach for sampling plastic at sea, and due to an inconsistent reporting scheme, datasets are rarely comparable (Whitacre, 2012).

iv. Microplastic abundance seems to differ with depth in the water column. This mainly concerns very small debris (10 µm or 0.01 mm) that present different sinking rates compared to larger microplastics (Enders et al. 2015). It appears that the abundance of larger debris (e.g. 1 mm) decreases with depth, and therefore concentrates mainly in the surface layer. Smaller debris (10 µm) show a relatively constant and high abundance from 0 to 100 m depth. Additionally, another study discovered that the abundance of < 300 µm debris increased with depth, with artificial fibres accounting for the main plastic type in the water column (Dai et al. 2018).

v. There are uncertainties regarding settling rates of microplastics from the surface to the seafloor with two main factors influencing this process: biofouling and water stratification.
Biofouling: is defined as "the accumulation of organisms on submerged surfaces affecting the hydrophobicity and buoyancy of plastic" (Kooi et al. 2017). Once loaded with organic matter, particles start to oscillate in the water column in different ways, depending on the photosynthesis rate (Kooi et al. 2017).
Water stratification and circulation: water bodies of different densities occur in some oceans and seas such as the Mediterranean. For example, surface and deep-water masses display independent circulation patterns but up to now, the influence of this circulation on plastic transfer toward the deep sea has not been documented (El-Geziry and Bryden, 2010).

> *There is a debate in the scientific community regarding the spatial distribution and fate of plastics in the water column. It appears unclear as to whether plastics sink and hence accumulate in the deep-sea and/or may be accumulated in the food web or oscillating in the water column.*

Analysing plastic samples relies upon very manual procedures, ultimately slowing down the processes and thus reducing the extent of sampling areas. Developing more automated measurement protocols, for example based on machine learning, would enable considerable progress in this field. Also, tracing specific particles such as tyre dust would be required to validate orders of magnitude provided by top-down modelling.

CONCLUSION

There is no simple solution to this complex and global issue. Policy makers and industries are currently taking decisions in a situation of high uncertainties. We should not forget that in some cases, plastic materials provide far more environmental benefits than drawbacks, for example when lighter material leads to reduced CO_2 emissions during transport.

We can manage only what we can measure. Efficient metrics accounting for plastic pollution are needed in order to guide sound eco-design and waste management strategies, while accounting for complex environmental impact trade-offs.

Despite all the urgency of action and the need for efficient metrics, it should not be forgotten that common-sense solutions rely on the avoidance of littering or plastic over-usage, and such solutions need to be activated immediately. In addition, sound waste management strategies would be beneficial in areas where they are lacking, in addition to public awareness. These are small-scale actions, yet achievable and would contribute to erasing our plastic footprint from the marine environment.

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3. REINVENTING THE FUTURE OF PLASTIC

At a time when plastic is under the spotlight, two seemingly opposed solutions are often mentioned. Some people dream of a deplastified world, where plastic is replaced by alternative materials. Many of these alternatives are yet to be invented, but one of the solutions proposed is to boost the amount of bio-sourced plastic produced (bio-PE, bio-PET etc.). Although more of this material has been produced in recent years, it remains controversial as it uses farm land to grow non-food goods but does not address the environmental impact of managing the resultant waste.

Indeed, the idea of systematically replacing plastics is not as simple as it seems: product life cycle analyses show that in some cases plastic is the best solution. For instance, replacing airline meal trays, formerly made of metal, with plastic produces major savings in terms of CO_2 and costs.

On the other hand, organizations such as the Ellen MacArthur Foundation feel that the question of plastic is emblematic of a need to move beyond the throwaway society with its take-make-dispose mantra, aiming instead to establish a circular economy that uses resources more responsibly; 95% of the value embedded in plastic packaging materials is lost every year, worth somewhere between $80 billion and $120 billion.

How can we wean ourselves from a society of waste to a society of resources? This entails reimagining our systems from top to bottom, from how objects are designed to how their end of life is managed. These are innovations that impact the waste management value chain and will require us to look afresh at the skills and professions needed to deliver a circular economy. For example, robots are already used, at some sites, to optimize sorting and reduce the physical demands on operators. Blockchain can be used to set up digital platforms that make it easier to integrate the informal sector, a key link in the waste recycling chain in emerging economies, as shown by Plastic Bank in Haiti and the Philippines. This technology is win-win: less waste dumped in the sea and a source of revenue for the poorest.

Mobilizing stakeholders is central to the success of changing the economic model to one with a more circular approach. Innovative projects like Project STOP in Indonesia show how important it is to reach out to all stakeholders in a territory in order to develop efficient and effective recycling solutions. Consumers too are critical actors in terms of their consumption choices and waste-sorting practices. For example, Yoyo is a French startup that rewards citizens who improve their waste sorting.

Plastic pollution clearly poses the question of how to support growth in emerging economies, where frenetic development tends to occur without the requisite wastemanagement infrastructure being able to keep up. Many stakeholders are working to improve installations used to collect, store and process plastic waste, in particular in economies where large amounts of plastics leach into nature. For example, the Alliance to End Plastic Waste, announced in January 2019 with backing from 30-odd major global companies, is committed to investing over $1 billion – and hopes to hit $1.5 billion, over the next five years – to help roll out solutions to reduce and manage plastic waste and promote recycling.

Yet does homo detritus, the hidden face of *homo economicus*, really believe the planet can be saved simply by throwing things into the correct bin? Solving the plastic pollution conundrum requires more than better management of waste and the adoption of a circular economy. It is predicated on the question of fighting poverty and access to essential services in many emerging economies. A large portion of plastic waste in these countries comes from single-dose sachets of everyday items (shampoo, washing products, coffee, etc.), millions of which are sold every day. Similarly, vast numbers of plastic bottles are sold in emerging economies because of a shortage of access to quality drinking water.

The current controversy about plastic requires us, yet again, to look afresh at how we produce and consume, and at our global lifestyles in the broadest sense.

Fanny Arnaud
Review coordinator

TOWARDS A NEW PLASTICS ECONOMY

Sander Defruyt
Lead of the New Plastics Economy initiative, Ellen MacArthur Foundation

The Ellen MacArthur Foundation was launched in 2010 to accelerate the transition to a circular economy. Since its creation, the charity has emerged as a global thought leader, establishing the circular economy on the agenda of decision makers across business, government, and academia. The Foundation works with the support of its Knowledge Partners (Arup, IDEO, McKinsey & Company and SYSTEMIQ), its Global Partners (Danone, Google, H&M, Intesa Sanpaolo, NIKE Inc., Philips, Renault, Solvay, Unilever), and its Core Philanthropic Funders (SUN, MAVA, players of People's Postcode Lottery (GB)).

Sander Defruyt leads the New Plastics Economy initiative, an ambitious three-year initiative bringing together key stakeholders to rethink and redesign the future of plastics, starting with packaging.

KEYWORDS
- CIRCULAR ECONOMY
- NEW GLOBAL PLASTICS SYSTEM
- PACKAGING
- INNOVATION
- COOPERATION

Our current plastics system is broken: if we do not fundamentally change it, there could be more plastic than fish in the ocean by 2050. Globally, just 2% of plastic packaging is recycled back into packaging, while the vast majority ends up landfilled, incinerated, or in the environment. To build momentum towards a plastics system that works, the New Plastics Economy initiative was recently launched in 2016 to promote the transition towards a circular economy for plastics in which they never become waste. It works with businesses, governments, NGOs, academics, and other stakeholders to catalyse the move away from today's linear "take-make-dispose" model and redesign the global plastics system based on the principles of a circular economy.

It is crucial for everyone involved in the plastics industry to understand that we need to go beyond collecting and recycling more. Both are important but they are not enough – we need to redesign the entire plastics system by starting upstream, thinking carefully about what we put on the market. Problematic or unnecessary plastic packaging must be eliminated through innovation and new business models. All remaining plastic packaging needs to be reused, recycled, or composted in practice. Finally, all plastic packaging is made from as much recycled content as possible and free from substances of concern. The aim is to ensure that plastic never ends up as waste, or worse, polluting the environment. It will require innovations, exploring the use of new materials, and new business models.

What is the ambition of the "New Plastics Economy" initiative launched by the Ellen MacArthur Foundation in 2016?

The New Plastics Economy initiative was created to work with businesses, governments, NGOs, academics, and other stakeholders to catalyse the move away from today's linear "take-make-dispose" model and redesign the global plastics system based on the principles of a circular economy.

While plastics have become an integral part of our economy and daily lives, it has become clear that the system is broken.

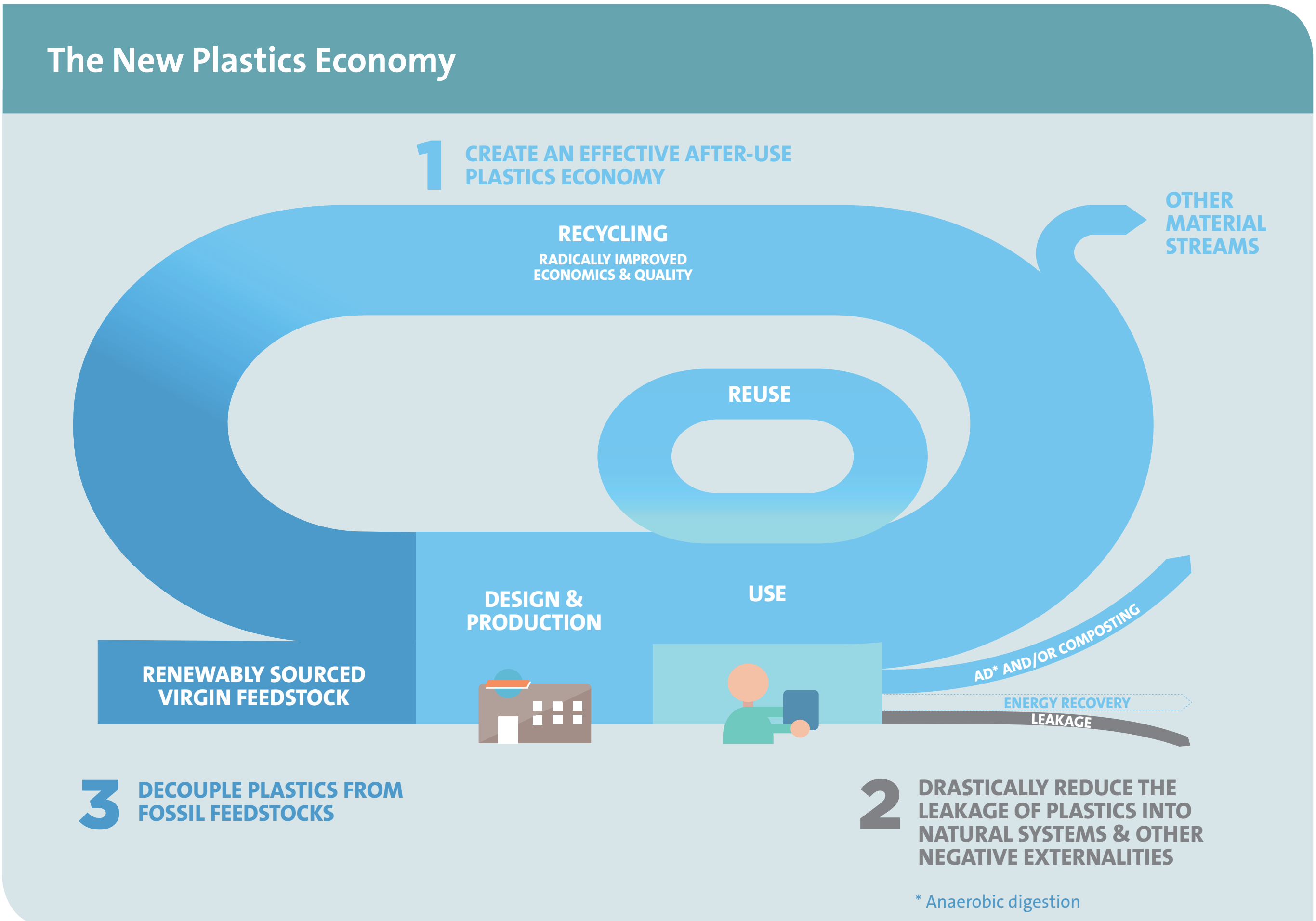
Globally, just 2% of plastic packaging is recycled back into packaging, while the vast majority ends up landfilled, incinerated, or in the environment. The three best known major international beach and ocean clean-ups jointly deal with less than 0.5% of the annual volume of plastic marine litter. Efforts to clean up waste are crucial for dealing with the symptoms, but do not address the root causes of the plastic problem we face.

Equally, rethinking the system is about more than just improving collection and recycling. While it is part of the solution, we cannot simply recycle our way out of the issues we face. We need to start thinking carefully about what we put on the market in the first place. For example, 30% of all plastic packaging items on the market today are either too small (e.g. small wrappers and sachets) or too complex (multi-layered materials) to be recycled. They require fundamental redesign and innovation.

By adopting the full system redesign set out by the New Plastics Economy, we can ensure plastics do not become waste and remain in the economy as a valuable material.

What are the main outcomes of the New Plastic Economy thus far?

Our first report, The New Plastics Economy – Rethinking the future of plastics, was published in January 2016 and laid out the drawbacks of today's broken system. The prospect of there being more plastic than fish in the ocean by 2050 if we do not fundamentally change our plastics system, captured global headlines and is still being referred to by media and others on a very regular basis. More importantly, the same report not only highlighted the problems but also put forward a vision of a plastics system that works – a circular economy for plastics in which they never become waste.



At the beginning of 2017, the second New Plastics Economy report laid out a more concrete action plan to realise the vision based on three pillars: redesign and innovation, reuse, and recycling. This again was endorsed by leading businesses and governments around the world.
More and more businesses and governments, as well as NGOs, academics, and other organisations are rallying behind this common vision, recognising that it provides a systemic solution that addresses the root causes of the plastics pollution crisis and not just the symptoms.

We also set up our USD 2 million Innovation Prize, which has inspired others to take action. Following this contest, several multi-million investment funds have been set up for creating a circular economy for plastics.

Recently, we launched our Global Commitment to draw a line in the sand against plastic waste and pollution.

What is the role of the New Plastics Economy Global Commitment and how will it make a difference?

To tackle the problem of plastic waste and pollution at source, the Ellen MacArthur Foundation, in collaboration with UN Environment, launched the New Plastics Economy Global Commitment at the 2018 Our Ocean Conference in Bali (Oct, 29). With over 250 signatories, the Global Commitment aims to catalyse action to radically change our current 'take-make-dispose' approach to plastic and make way for a system where waste and pollution are designed out. Signatories commit to eliminate the plastic items we do not need; innovate so all plastic we do need is designed to be safely reused, recycled, or composted; and circulate everything we use to keep it in the economy and out of the environment.

It is the largest effort ever to mobilise businesses behind targets that can be pivotal to help end the plastic pollution crisis: the more than 250 signatories together cover over 20% of the global plastic packaging market and the commitment is supported by WWF, and has been endorsed by the World Economic Forum, The Consumer Goods Forum (a CEO-led organisation representing some 400 retailers and manufacturers from 70 countries), and 40 universities. Five venture capital funds have made commitments to invest over $200 million by 2025 to create a circular economy for plastic and more than 15 financial institutions, including the European Investment Bank, with in excess of $2.5 trillion in assets under management have endorsed the Global Commitment.

How can leading brands, retailers, and packaging companies change their plastics habits?

Given the scale of the challenge, immediate action is absolutely required. Many signatories are capturing quick wins and we strongly encourage others to follow their lead. For example, Marks & Spencer is removing single use plastic cutlery and straws this year. Colgate Palmolive will eliminate PVC packaging by 2020 and others have eliminated PVC from their packaging already. Eliminating such unnecessary and problematic plastic is something that can be done very quickly. We encourage all signatories to prioritise actions like these as they can have a significant impact in a minimum amount of time.

Unfortunately, there is no easy, one-size-fits-all solution to realise these commitments. It will vary from business to business and government to government. What is clear though, is that to be successful we need to collaborate as we are changing a global system that involves and affects so many people and organisations. It is by working together and sharing knowledge and best practices that we can provide support to jointly achieve our commitments and develop circular solutions that will make everyone better off in the end.

How can we redesign the global plastic packaging market?

It is crucial for everyone involved in the plastics industry to understand that we need to go beyond collecting and recycling more. Both are important but they are not enough – we need to redesign the entire plastics system by starting upstream, thinking carefully about what we put on the market.

Problematic or unnecessary plastic packaging must be eliminated through innovation and new business models. All remaining plastic packaging needs to be reused, recycled, or composted in practice. Finally, all plastic packaging is made from as much recycled content as possible and free from substances of concern.

The aim is to ensure that plastic never ends up as waste, or worse, polluting the environment. It will require innovations, exploring the use of new materials, and new business models.

What are the examples of successful collaboration within the New Plastics Economy initiative?

Bringing together all the relevant stakeholders is at the core of the work of the New Plastics Economy initiative. A good example that highlights the importance of successful collaboration, is captured by our Pioneer Projects. These projects are all about cross-value chain collaboration and are initiated and run by businesses, using their expertise and knowledge to help tackle the barriers that we face in the transition towards a new plastics economy. They are pre-competitive collaborations that invite stakeholders from across the plastics industry to create and test innovations that could change the way we design, use, and reuse plastic packaging.

In the framework of the New Plastics Economy initiative, how do you develop initiatives at a local level ?

To create a New Plastics Economy we need ambitious efforts around the world with a shared vision. However, when it comes to implementing a new plastics economy, we still need solutions that are appropriate for their local context. The Plastics Pacts are precisely that: innovative, multi-stakeholder collaborations that help create a circular economy for plastics in their designated country or region within a specified timeframe.

Our team works to bring together all the key players involved in plastics at national or regional level. By collaborating with local stakeholders across the globe, we are creating a common agenda and setting ambitious 2025 targets. Through these pacts, a network national or regional frameworks will be set up so that countries can demonstrate their leadership and inspire and challenge one another.

The UK Plastics Pact is the first implementation of this wider international initiative. The pact is between UK businesses, governments, local authorities, NGOs, and citizens, addressing the need for collective action. It is led by UK charity WRAP and supported by the Ellen MacArthur Foundation. In Chile, 7,000 miles away, a second Plastics Pact is being prepared. After the UK and Chile, others will follow, all with the same vision – the creation of a new plastics economy.

What are the innovative approaches to develop new models for making better use of packaging?

There are numerous examples of innovative ways of "going circular" for plastics packaging. For instance, MIWA, from the Czech Republic, introduced an app that lets shoppers order the exact quantities of the groceries they need, which are then delivered in reusable packaging from the producer to their closest store or to their home. By connecting the producer with the consumer, the concept of package-free stores is taken to an even further level. This way single-use packaging is completely eliminated along the product's value chain.

Algramo, a Chilean social enterprise, offers products in small quantities in reusable containers across a network of 1,200 local convenience stores in Chile, reaching more than 200,000 customers. Targeting economies where recycling infrastructure is limited and small packaging items such as sachets often end up in the environment, Algramo introduces a reusable packaging system with dispensers and affordable containers. While dispenser systems are not new, Algramo is at the forefront of making them a frugal and robust system for markets where single-use sachets are the most prominent form of packaging, and where designing them out will have the biggest impact.

Australian company Splosh provides customers with refills in dissolvable sachets, which they can mix with water in a refillable bottle at home.

How do you see the global plastics economy in five-ten years?

While the commitment already represented 20% of the global plastic packaging industry on the day it was launched, more businesses and governments need to join and become part of this unstoppable momentum to help create a plastic system that works – one that provides benefits for society, the economy, and the environment.

Since the launch, more organisations have signed up every week. In five years, businesses should have eliminated problematic and unnecessary plastics packaging, ensured the rest of their packaging is reused, recycled, or composted, and the use of recycled content will have been greatly increased – drastically reducing the need for virgin fossil-based materials.

TURNING THE NETHERLANDS INTO A PLASTIC CIRCULAR HOTSPOT

Hildagarde McCarville
CEO, Veolia Netherlands

Veolia is the global leader in optimized resource management. With nearly 169,000 employees on five continents, the Group designs and provides water, waste and energy management solutions that contribute to the sustainable development of communities and industries.

Hildagarde is the CEO of Veolia Netherlands and is a non-executive director of Veolia Ireland.

Prior to this, Hildagarde was the CEO of Dalkia, having transferred to the Netherlands from Dublin, where she was the Finance & Support Services Director of Dalkia Ireland.

KEYWORDS

- CIRCULAR ECONOMY
- CIRCULAR HOTSPOT
- NETHERLANDS
- INNOVATION
- RAW MATERIAL

The Netherlands has a longstanding, ambitious environmental policy with regard to the recovery and recycling of materials. Currently, 79%[1] of its waste is recycled and the residual waste is mainly used for energy generation, which in turn is part of the solution toward a shift in energy production through renewables. The initiative "Netherlands as Circular Hotspot" aims at positioning the Netherlands as an international example for circular business and develop a circular economy in the Netherlands by 2050. Based on this political ambition, the Dutch ecosystem has started a transition toward a circular economy. The plastics recycling market in the Netherlands is constantly evolving in parallel with the adaptation of more circular business models due to the impact of climate change and resource scarcity.

To accompany the intense development of the circular economy in the Netherlands, Veolia decided to acquire in 2015 a Dutch company named AKG Polymers that now has almost 50 years of experience in plastics recycling. This plant in the Netherlands is now Veolia's global center of excellence for recycling polypropylene. Veolia is accompanying brands, such as Philips, in their commitments to making their products and services more environmentally friendly. This innovative dynamic around recycling is also encouraged by a more collaborative approach, breaking down the traditional silos, and creating new markets and business models in the Netherlands and abroad.

INTRODUCTION

Since the 1960s, the Dutch economy has strongly relied on gas following the discovery of the largest gas field in Europe, the Groningen field, and the tenth largest in the world. The Netherlands became the EU's largest natural gas-producing country. This abundance of gas facilitated the development of energy-intensive industries, notably refining, petrochemicals and agriculture. Holland represents one of Europe's leading suppliers of chemical products and services and boasts more than 400 top chemical companies across the entire supply chain. The Port of Rotterdam, Europe's largest port, is one of the strongest refining and chemical clusters in the world. Second only to the United States for agri-food exports worldwide, more than 4,150 companies are established in this key sector and the Netherlands hosts major production or R&D sites of 12 of the world's largest agri-food companies.

This well-established, gas-oriented economy has recently known major shifts. A big turning point was the progressive decision to reduce natural gas production in response to popular and parliamentarian environmental pressures.

1 Ministry of Infrastructure and Water Management of the Netherlands

In March 2018, the Dutch government announced that it will phase out gas production at the Groningen field by 2030 as part of efforts to reduce the danger caused by small but damaging earthquakes.

TOWARD "HOLLAND CIRCULAR HOTSPOT"[2]

Presently, the Netherlands remains one of the most fossil-fuel (gas) and CO_2-intensive economies among International Energy Agency member countries[3]. However, its goal is to switch from a gas-intensive economy to a gas-free future. It is implementing a national energy transition to achieve a CO_2 neutral energy supply system by 2050. The first steps are already in progress; for example, in 2017, 10,000 buildings in Amsterdam were disconnected from the gas grid[4]. In the words of the Dutch Ministry of Economic Affairs, the energy policy will work on three main principles: "1) focus on CO_2 reduction; 2) make the most of the economic opportunities that the energy transition offers and 3) integrate energy in spatial planning policy"[5]. The Netherlands is pursuing a rigorous climate policy to reduce greenhouse gases by 95% by 2050 compared to 1990 levels through a large-scale transformation of energy generation, carbon capture, industrial symbiosis, and becoming circular in nature.

The Netherlands has a longstanding, ambitious environmental policy with regard to the recovery and recycling of materials. Currently, 79%[6] of its waste is recycled and the residual waste is mainly used for energy generation, which in turn is part of the solution toward a shift in energy production through renewables. The goal, however, is to position the Netherlands as the circular economy pioneer.

The campaign "Netherlands as Circular Hotspot", launched during the Dutch presidency of the EU in 2016 and sponsored by Dutch companies, aims at positioning the Netherlands as an international example for circular business. The goal is to develop a circular economy in the Netherlands by 2050. In its national program launched in September 2016, the government selected five economic sectors and value chains that will be the first to switch to a circular economy, due to their importance to the Dutch economy and the environment. Plastics is one of these top priorities, with the goal of using only renewable (recycled and biobased) plastics by 2050.

Based on this political ambition, the Dutch ecosystem has started a transition toward a circular economy. Major Dutch companies, such as Philips, and public authorities, like the Port of Rotterdam, have embarked on a journey to change their business models, from a linear to a circular approach. In 2018, the Dutch financial institution ING launched a fund committing €100 million of capital for investments to support sustainable "scale ups" with a proven concept and a positive environmental impact. The goal is to invest in companies within the Circular Economy and Energy Transition fields.

BOOSTING PLASTICS RECYCLING IN THE NETHERLANDS

To accompany the intense development of the circular economy in the Netherlands, Veolia decided to acquire in 2015 a Dutch company named AKG Polymers that had almost 50 years of experience in plastics recycling. The company was founded in 1969 by an entrepreneur who was recycling scrapped clothing hangers, and is now one of the European market leaders in recycling and compounding of polypropylene (PP) plastic. The recycling plant is located in Vroomshoop, in the east of the Netherlands and near to the renowned Polymer Science Park, a leading open innovation center in the field of applied plastics technology and close to where Veolia has its washing and flaking facilities.

The Veolia production plant produces high quality compounds made from recycled polypropylene (PP), coming from recovered commercial, industrial and household waste (90% of supplies) and from the waste produced by plastic product manufacturers.

PP compounds produced at Veolia's plant in Vroomshoop, Netherlands

2 Campaign that positioned the Netherlands as an international circular economy (CE) hotspot during the time of the Dutch Presidency of the EU in 2016.

3 International Energy Agency

4 www.citylab.com

5 Ministry of Economic Affairs of the Netherlands, *Energy Report Transition to sustainable energy*, April 2016

6 Ministry of Infrastructure and Water Management of the Netherlands

PP compounds produced at Veolia's plant in Vroomshoop, Netherlands

PP is a modern and versatile plastic that is used in countless products. The number of applications continues to grow on a daily basis. PP is highly suitable for recycling. Its properties can be easily modified, for a second, third or even a tenth life, whether for the same or a totally different application. The recycled PP compounds are sold to different producers of plastic products, substituting virgin plastics. They are used in many fields such as automobile components, garden furniture, household appliances (vacuum cleaners, coffee machines), various storage systems (crates, boxes), piping and water drainage systems.

The plastics recycling market in the Netherlands is constantly evolving in parallel with the adaptation of more circular business models due to the impact of climate change and resource scarcity.

Smart recycling maintains the value of PP, conserves scarce mineral resources such as oil, and protects the environment as the energy consumed and carbon footprint arising from producing 1 metric ton of PP compounds made from recycled material is much lower than that consumed in the production of 1 metric ton of virgin plastic resins.

This plant in the Netherlands is Veolia's global center of excellence for recycling polypropylene. Its laboratory is equipped with state-of-the-art technologies, and is able to supply complete analyses at each step of the production process, thus ensuring Veolia guarantees the highest quality product to our end customer. While Veolia does not have traditional waste facilities in the Netherlands for the direct collection and sorting of municipal waste, it does operate a right of first refusal policy or "RoFR" with other Veolia business units across Europe. This enables the purchasing department in Vroomshoop to source quality input feedstocks at market prices once sorted at other Veolia locations and convert these PP bales into flakes in Vroomshoop. The location of the plant is a great advantage as it can easily have access to main European feedstock producers (UK, France, Germany, Belgium and Luxembourg).

Within a few months of the acquisition, AKG was integrated into the Veolia organization and thanks to a multiyear growth program, it has been able to increase its production capacity from 35,000 metric tons in 2015 to 50,000 metric tons in 2018.

CIRCULAR MARKET TRANSFORMATION ACCELERATION

Veolia has traditionally accompanied some brands such as Philips in their commitments to making their products and services more environmentally friendly. Philips wants to eco-design its products and services with a focus on circularity. By 2020, it plans for 70% of its revenue to come from “green” products and 15% from “circular products”. To achieve this, Philips has decided to increase the proportion of recycled materials used in production.

The cooperation between Philips and Veolia began in 2010 with the development of a new kind of vacuum cleaner. At that time, Veolia developed a material from recycled battery shells. Today, after several generations of cleaning appliances made from waste plastic, the Philips green vacuum cleaners contain between 25% and 47% recycled polypropylene.

In the Netherlands, Veolia is involved very early on in the manufacturing process, right from the design stage. Its role is to help Philips integrate as much recycled plastic as possible, in this case polypropylene, into its new models of vacuum cleaners and coffee machines, and thereafter to supply Philips with materials to meet its requirements and to ensure a regular (in quantity) and constant (in quality) supply. As a result of this partnership, Philips and Veolia are currently studying the possibility of using plastic from the manufacturer’s end-of-life appliances to produce recycled plastic.

Philips vacuum cleaner

The closed loop approach of Veolia goes even one step further with partnerships such as the one developed with the company Polypipe who manufactures piping and water drainage systems. Not only do they use Veolia’s recycled plastics to make their products, but in turn Veolia can display these said products in their offerings to cities. For companies such as Polypipe the use of recyclate materials is their USP (“Unique Selling Proposition”).

CONCLUSION

The plastics recycling market in the Netherlands is constantly evolving in parallel with the adaptation of more circular business models due to the impact of climate change and resource scarcity. In February 2019, 65 companies including DSM, Philips, will sign the Dutch Plastic Pact aiming to increase the use of recyclates. This innovative dynamic around recycling is also encouraged by a more collaborative approach, breaking down the traditional silos, and in turn creating new markets and business models.

Two examples of this are:

(i) IKEA, which acquired a 15% minority stake in Dutch plastics recycling plant Morssinkhof Rymoplast, as part of a €3 billion budget allocated by the company to sustainability investments. IKEA's investment in Morssinkhof Rymoplast builds on the company’s goal of making its plastic products (representing around 40% of its total plastic use) using 100% recyclable and/or recycled materials by 2020.

(ii) LyondellBasell's acquisition of a stake in QCP, a Dutch producer of recycled plastic compounds that it owns jointly with Suez. This represents a partnership in the Netherlands between one of the largest plastics, chemicals and refining companies and a waste management player to contribute to circular economy objectives.

The ongoing development of a plastic circular economy also relies on technology innovation, such as the development of chemical treatment of plastics (instead of mechanical treatment) and on standardization and certification of recycled plastics to improve the quality and purity of plastics.

PROJECT STOP: CITY PARTNERSHIPS TO PREVENT OCEAN PLASTICS IN INDONESIA

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SYSTEMIQ was established in 2016 to catalyze good disruptions across energy, land use and industrial systems. The company has offices in London, Jakarta and Munich. www.systemiq.earth

Borealis is a leading provider of innovative solutions in the fields of polyolefins, base chemicals and fertilizers, and is recognized as a circular economy leader within this industry due to its recent investments in plastics recycling and its role as an active member of key industry initiatives. www.borealisgroup.com

Veolia is the global leader in optimized resource management. www.veolia.com

Project STOP is co-funded by Borealis and SYSTEMIQ, the Government of Norway, NOVA Chemicals, and Borouge. It is also supported by the Indonesian Ministry of Environment and Forestry and Banyuwangi Regency. Veolia and Sustainable Waste Indonesia are technical partners for the project. www.stopoceanplastics.com

KEYWORDS

- ACTION-INNOVATION PARTNERSHIPS
- ZERO LEAKAGE SYSTEM
- INFORMAL SECTOR
- PLASTIC VALUE CHAIN

An estimated 80% of marine plastic litter comes from land-based sources, with 50% originating from just five Asian economies: China, Indonesia, the Philippines, Vietnam and Thailand[1]. As economic growth has increased in these countries, so has plastic consumption, which has outpaced the development of effective solid waste management systems. That is why the first STOP city partnership was launched in 2018 in Muncar, a city of 130,000 residents in Banyuwangi Regency, East Java, Indonesia. The goal of Project STOP is to create an economically viable "zero leakage" system that involves state-based systems, communities and the informal sector, and that can be sustained through secure government revenues, household and business collection fees and valorization of waste.

Project STOP has three objectives: zero leakage of waste into the environment; increased resource efficiency and recycling of plastics; and benefits for the local community by creating new jobs in the waste management system and reducing the impacts of mismanaged waste on public health, tourism and fisheries.

Early insights from Project STOP's scoping activities, system design and first six months of system change implementation are presented in three areas: 1) An integrated "value chain engineering" approach is key to system change, 2) Institutions, governance and community factors are critical, 3) Economic incentives are a great tool to develop recycling initiatives.

Action-innovation partnerships at the city level – Project STOP and many others – can provide much-needed insight into the challenges and potential solutions that could accelerate change toward a plastic system that works, and an environment free from plastic waste.

INTRODUCTION

Littering of plastics into natural ecosystems, particularly oceans, has fast emerged as an iconic environmental issue supported by increasing public and political momentum. Each year, 8 million tons of plastics enter the ocean[1], a visible symptom of our increasing use of "single-use" plastics and our failure to provide proper waste management systems for many communities across the developing world.

Project STOP is a new city partnership program that gets to the front line of the plastic leakage problem in Southeast Asia. The first STOP city partnership was launched in 2018 in Muncar, a city of 130,000 residents in Banyuwangi Regency, East Java, Indonesia. With minimal waste services in place, residents are forced to dump their waste directly into the environment. Muncar was chosen as the first

1 Jenna R. Jambeck et al., "Plastic Waste Inputs from Land into the Ocean," Science 347, no. 6223 (2015): 768–71, doi:10.1126/science.1260352.

Muncar community outreach

Polluted beach in Muncar

The goal of Project STOP is to create an economically viable "zero leakage" system that involves state-based systems, communities and the informal sector, and that can be sustained through secure government revenues, household collection fees and valorization of waste.

STOP location due to the seriousness of the challenge, coupled with strong leadership and environmental commitment at national, regency and local levels. According to a recent community survey, households here generate roughly 40 tons of waste per day, while 90% of the community is without waste services. Through Project STOP, an increasing number of Muncar households and business are receiving waste collection and recycling processing, some for the first time.

Cleanup activities provide a short-term respite and opportunity for public engagement, but they have little sustainable impact on the plastic litter challenge. We must turn off the tap. Alongside "upstream" initiatives to eliminate unnecessary plastic use and improve product design, waste management and recycling solutions at the city or municipality level are critical in stemming the tide of plastic littering into nature.

This article provides some early insights from the scoping and implementation of this initiative.

PLASTIC LITTER IN INDONESIA: A SYSTEM FAILURE WITH ENVIRONMENTAL AND SOCIOECONOMIC CONSEQUENCES

Plastic is a remarkable material with highly valued properties that have made it central to modern life – it is durable, lightweight and often more affordable than alternative materials, with benefits for climate change mitigation and energy and water savings throughout their use phase.[2]

These properties come with a downside: its durability means that plastic can take hundreds of years to degrade in nature, its light weight means it is easily transported by wind and water, and its affordability means that the economics of recovering and recycling some single-use plastic items are challenging.

According to the UN, plastic waste costs a minimum of $13 billion in damage to marine ecosystems worldwide. Unabated and increasing plastic leakage could force this number to climb higher, affecting lives and livelihoods dependent on critical industries including fishing and shipping.

In Indonesia, the challenge is acute: current estimates show that only 45-60% of Indonesia's urban solid waste is collected, with significant variation in performance

2 Reference: TruCost: https://plastics.americanchemistry.com/Study-from-Trucost-Finds-Plastics-Reduce-Environmental-Costs/

Muncar community outreach beach cleanup

among cities.[3] As a result, leakage – largely a result of poor waste management systems – contributes to reduced tourism and fishing productivity, which are both lifelines to the Indonesian economy. In 2017 travel and tourism in Indonesia, for example, directly accounted for 3.7% of total employment and 5.8% of GDP.[4]

In response, the Indonesian government announced a bold commitment to reduce Indonesia's ocean plastic levels by 70% by 2025, creating a National Marine Debris Action Plan. Delivery of its commitment relies on a rapid acceleration of waste management systems at the city level, combined with system-level policy, innovation and circular material design approaches.

SYSTEM SOLUTIONS TO PREVENT PLASTIC LITTERING

Reduction or elimination of unnecessary and avoidable plastic use must play a key role in reducing plastic litter. Alongside these solutions, there is a need to rapidly accelerate efficient waste collection and recycling systems in high leakage markets, while considering the local context, particularly the informal waste collection and trading economy that provides many livelihoods.

Innovation, design and "learning by doing" are critical for both upstream and downstream system solutions – including new materials, new products and business models, new behavior change approaches, financing and design of collection systems and integration of informal waste collectors, and re-processing technologies that can extract more value from plastic waste.

FRONT LINE ACTION-INNOVATION PARTNERSHIPS AT THE CITY LEVEL: PROJECT STOP

Project STOP was founded in mid-2017 by Borealis and SYSTEMIQ. The project establishes city partnerships to design and implement low-cost waste management systems with strong institutions and long-term financial viability, effective waste collection and sorting services, community behavior change campaigns and new waste management infrastructure. The STOP team uses a "system-enabler" approach to support cities with co-investment, technical expertise, project management and assisted implementation, skills transfer and support with recycling/valorization options.

Project STOP has three objectives:

1. Zero leakage of waste into the environment.

2. Increased resource efficiency and recycling of plastics.

3. Benefits for the local community by creating new jobs in the waste management system and reducing the impacts of mismanaged waste on public health, tourism and fisheries.

3 Indonesia Marine Debris, Hotspot Rapid Assessment, April 2018, World Bank Group, Kementerian Koordinator Bidang Kemaritiman, Embassy of Denmark, Royal Norwegian Embassy

4 Travel & Tourism Economic Impact 2018 Indonesia, World Travel and Tourism Council

Waste collection

EARLY INSIGHTS FROM PROJECT STOP

Early insights from our scoping activities, system design and the first six months of system change implementation are presented in three areas:

1. CIRCULAR ECONOMY SOLUTIONS REQUIRE "VALUE CHAIN ENGINEERING"

The greatest paradox of Project STOP scoping studies comes from meeting recycling companies or investors crying out for plastic feedstock, while also seeing the flows and accumulations of plastic waste in the environment and hearing the concerns of government officials over dwindling capacity at landfill sites. This is symptomatic of a broken value chain where single interventions in one part of the system have a low chance of success.

Serious efforts to close the loop and build a circular plastics economy in high leakage markets must take an integrated value chain approach, for example:

- Integrating waste collection improvements with sorting, logistics, waste processing and recycling systems (and vice versa) to valorize waste, provide secure feedstock supply to enable recycling investments, and remove the strong disincentive to collecting waste felt by local agencies with constrained landfill capacity.
- Informing and engaging producers of plastic products (e.g., packaged goods companies) to design materials and products for ease of collection and sorting and higher recyclability in the after-use systems in high leakage markets as well as in developed markets.
- Engaging the informal waste collection and trading system as well as state-based or community waste management systems, in order to recognize that the waste system will continue to be a hybrid model and seek to protect and improve livelihoods, worker rights and working conditions in the informal waste economy.
- Integrating the approach to plastic waste – around 14% of the waste stream – with other waste stream components, particularly organic materials that are costly to collect and process. In some locations, for example lower density areas, it may be preferable to focus on plastic waste collection with local treatment of biodegradable waste. In high density areas this may not be feasible or supported by communities and government decision-makers, so an adaptive and locally driven approach is likely to be required.

2. WE IGNORE THE ECOLOGY OF WASTE – INSTITUTIONS, GOVERNANCE AND COMMUNITY SYSTEMS – AT OUR PERIL

In Indonesia, waste management is decentralized to the city or regency level, with many accountabilities further delegated down to sub-district, village and neighborhood level. For example, land and approvals for waste management sites typically require approval at the village level, and household collection services are typically managed at the neighborhood level. Extreme decentralization is a challenge to rapid system change and replication of good practices.

Even with these challenges, Project STOP has built positive community momentum in three key areas:

- Establishing and training community businesses (known as BUMDES in Indonesia) to operate community waste management facilities and trade recyclables.

Muncar collection team

- Building confidence and momentum by taking community leaders on a "good practice waste management tour" to see effective circular waste management systems in other parts of Indonesia.
- Engaging community institutions – particularly women's associations, fishing associations and religious leaders – and involving them in communication campaigns, house-to-house community engagement activities and beach clean-ups.

3. MONEY TALKS

Money talks in a very visible way in Indonesia. Within a reasonable distance of a plastics recycling hub, plastic bottles are very hard to find in the waste stream or in waste accumulation hotspots. They are far too valuable for that – at an estimated value of $350 per ton, these plastic items are highly sought after by informal waste collectors, waste banks and traders. Flexible and multi-layer plastics command a lower price, are harder to collect and are more prone to contamination. However, economic incentives to sustainably increase the price of lower value plastics (e.g., through price support for recyclers, waste collectors, traders, waste banks and state-run waste sorting facilities) could be a key tool to increase their collection through informal, state-based and hybrid systems.

The goal of Project STOP is to create an economically viable "zero leakage" system that involves state-based systems, communities and the informal sector, and that can be sustained through secure government revenues, household collection fees, industry contribution and valorization of waste. Cherry-picking of high value plastics into the informal economy is a fact of life and increases the economic pressure on waste systems. While it is too early to publish findings on waste system economics in Muncar, we can safely say that financing city waste management systems and plastic waste recovery through the informal waste economy (in Muncar and other cities in Indonesia and across the region) is a central issue for solving the plastic litter crisis.

A financing breakthrough is needed to accelerate plastic waste recovery and recycling in high leakage markets

A financing breakthrough is needed to accelerate plastic waste recovery and recycling in high leakage markets. This could take many forms, for example:

- Designing an effective extended producer responsibility (EPR) system to enable industry financing of recovery and recycling through state-based and informal systems.
- Guaranteeing a high and stable price for post-consumer recycled plastic to pull material through the system.
- Deploying new processing technology that can derive more value from waste (and pay more for feedstock).
- Driving a product and packaging design revolution that transforms after-use value of plastic materials for recyclers.

Building convergence, support and momentum behind these strategies requires data and proof points from the front line. This will be one objective for Project STOP as we aim to drive direct impact on plastic leakage and also collaborate with others to extract the key learnings for replicating, scale-up and acceleration of zero-leakage systems and the enabling policies and actions required to achieve this.

CONCLUSION

Action-innovation partnerships at the city level – including Project STOP and others – can provide much-needed insight into the challenges and potential solutions that could accelerate change toward a plastic system that works, and an environment free from plastic waste. To learn more about Project STOP, please visit www.stopoceanplastics.com.

Follow Project Stop on Twitter @EndOceanPlastics

Project STOP - The City of Muncar

The first Project STOP city partnership is in Muncar, a coastal fishing community in Banyuwangi, Indonesia. With minimal waste services in place, the majority of citizens are forced to dump their waste directly into the environment. Muncar, home to more than 130,000 people, was chosen as the first STOP location due to the seriousness of the challenge, coupled with strong leadership and environmental commitment at national, regency and local levels.

CHALLENGE

A coastal city, home to **130,000 PEOPLE**

MUNCAR

Households generate roughly **40 TONS OF WASTE PER DAY**

90% OF THE COMMUNITY is without waste services

SO FAR, PROJECT STOP HAS

CALLED ON
+12
INTERNATIONAL SOLID WASTE EXPERTS
to design the system

REMOVED
+70
TONS OF MATERIAL
from the local beaches, of which **< 25% was plastic**

UPGRADED
1
WASTE PROCESSING FACILITY
which could process waste from more than half of Muncar's population

SORTED
14 GRADES OF PLASTIC / 5 GRADES OF PAPER
along with scrap metals and glass

USED
BIOCONVERSION
through producing black soldier fly larvae and composting organic waste, thus maximizing the value of the waste stream

PREVENTED
22.5
TONS OF PLASTIC
(91.9 tons of waste) from entering into the environment through introducing door-to-door collection and hotspot cleanups

GOAL BY END-2020

130,000 PEOPLE
served with formalized waste collection

100+ NEW JOBS
created

1,000 TONS/YEAR
PERMANENT REDUCTION OF OCEAN PLASTIC LEAKAGE

YOYO: RECYCLING ALL PLASTIC. IMPOSSIBLE? WE'VE ALREADY STARTED!

The Yoyo team

Yoyo is a collaborative platform that rewards inhabitants who sort more and better their used plastic bottles so that these can be directly recycled in a French-based short circuit.

Yoyo is a digital startup founded in 2017 by Éric Brac de la Perrière. A graduate of France's Institute of Advanced National Defense Studies, he managed several communications companies before being appointed in 2009 head of Eco-Emballages, the body responsible for organizing recycling of household packaging waste in France. Eight years later he created a new and innovative project, one designed to deliver faster and better to tackle plastic pollution quickly and efficiently. His idea is to roll out a positive, complex-free approach to grassroots ecology, giving everybody the tools and motivation to cut the impact of their consumption.

KEYWORDS

- POSITIVE ECOLOGY
- COMBATING PLASTIC POLLUTION
- COMMUNITIES
- RECYCLING IN SHORT CIRCUITS

By 2025, almost 80% of the world's population will live in densely populated areas. Cities produce mountains of waste, consuming the most and sorting the least; plastic recycling reaches only 20% in urban areas. We are at a defining moment. If we want our lifestyles to become sustainable, we will all have to learn new ways of dealing with our household waste. Faced with this situation, city-dweller communities were determined to act. They decided to join together to embody the vitally needed change – bottle by bottle – and that's how Yoyo was born.

Yoyo.eco is a digital and human solution that rewards people who sort more and better to offset the environmental impact of what they consume. In 2018, Yoyo was operational in six cities and its 15,000 sorter residents had recycled 2 million bottles via a French-based short recycling circuit. Yoyo has proved that with resolutely positive ecology it is possible to double the amount of plastic recycled in French cities – and reduce drastically plastic pollution.

WHY YOYO?

THE COMPANY'S ORIGIN AND AIMS

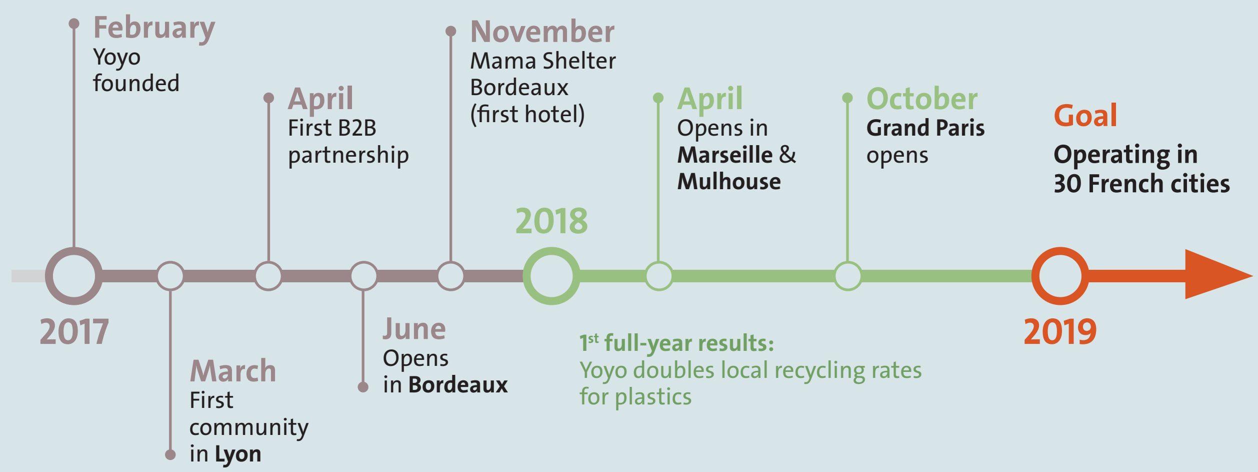
Humanity faces some alarming environmental challenges. First is the 300 kilos of plastic released into the world's oceans every second. Next, and this is the founding idea behind Yoyo, is the fact that cities are where people consume the most but recycle the least. Today, close to 75% of French people live in urban areas, yet average plastic recycling rates are flatlining at around 20%.

The public policy environment favors better recycling performance and setting up new mechanisms to run alongside existing waste collection organizations. The aim is to recycle 100% of plastics by 2025. France's roadmap for a circular economy favors positive initiatives in the social and solidarity economy.

Yoyo is a company that works with public and private sector partners to roll out a project to double neighborhood plastic recycling rates. Its aim is to combat pollution in cities by capturing 100% of waste plastic flows. The plan is to reach out to those who sort the most and the best. Yoyo works by rewarding people for sorting carefully, mobilizing communities of like-minded locals. By sharing their best practices, we help people to reduce the impact of their day-to-day consumption.

Yoyo uses green-awareness to build neighborhood social ties, pulling together all the actors in any given area to achieve the goal of recycling all plastics by 2025. Yoyo also delivers 100% traceability for plastics and, most important of all, a community of coaches and sorters whose plastics recycling rate improves from 20% to 90% in a single year.

Development milestones



WHAT IS YOYO?

RECYCLING ALL PLASTIC – IS IT IMPOSSIBLE? WE'VE ALREADY MADE A START!

The way that Yoyo works is actually quite simple. We set up in an area and set to work with a very wide range of actors. We partner with waste collection authorities and local government as well as businesses, bottled water companies, retailers and public venues such as Pathé cinemas and the Mama Shelter and Novotel hotel chains.

The Yoyo system is simple: sorters sign up to the platform in three clicks, they then choose the Coach nearest to them, drop in to pick up their first bag, and then start filling it with plastic bottles. Once full, the bags are returned to the Coach. This is when Coach and sorter are rewarded for their involvement. Once the Coach's storage space is full, we request a pick-up and deliver the bottles to the nearest recycling center, ensuring that 100% of recycling follows a short circuit and stays in France.

KEY LEVERS

The rewards system is Yoyo's number one lever: we reward careful sorting with tickets to the cinema or a soccer match, a range of environmentally friendly products, etc. Rewards are by far the leading driver for getting people involved.

Yoyo's other lever is the Coach. Coaches create and maintain their sorter community. They strengthen neighborhood social ties and help put people in need in contact with social centers and nonprofits. We provide our coaches with support and training to help them increase their skills and knowledge. Our aim is to have every Coach become a true local ambassador, spreading the word in their neighborhood about how to help the environment.

TESTIMONY FROM THIERRY HERPIN

Picture-framer and Yoyo Coach (Bordeaux - France)

I was the very first Yoyo Coach of all! I can store 70 bags at my workplace. I trigger a pick-up from the platform about once a month and Yoyo sends a truck round the next day. It's really no bother! I signed up in July 2017 and I'll soon be packing off my 1,000th bag – something I'm very proud of.

I've swapped all the points I've earned for gifts for people in need: tickets to the museum for kids who've dropped out of school, cinema tickets for the local Red Cross and so on. I donate everything to local nonprofits.

I know it's a drop in the ocean, but at least I'm doing my bit, like the hummingbird.

Yoyo in figures

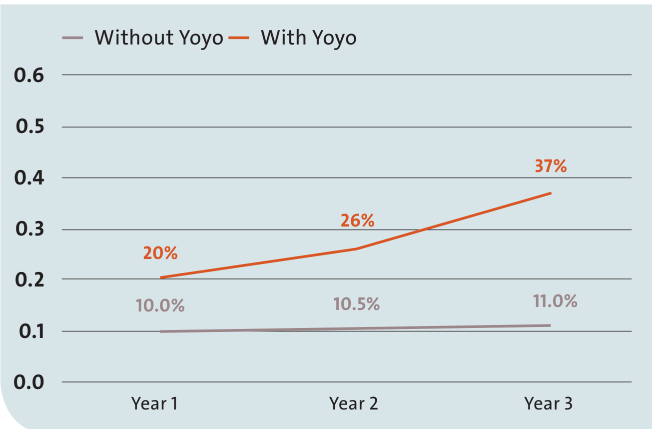
ABOVE ALL, YOYO IS A TOOL FOR MOBILIZING SORTER COMMUNITIES

The rewards-based approach helps Yoyo raise people's awareness about wider environmental challenges. For example, we're seeing a 15% uplift in recycling rates for other materials in neighborhoods where we operate.

In a more general sense, local people become more aware of the impact their consumption has, thanks to a range of actions run in partnership with city governments and local nonprofits, such as litter cleanups, visits to waste sorting centers, workshops, training sessions, etc. Members of the Yoyo community discover and adopt environmentally friendly practices as part of their everyday lives, joining a wider movement to improve management of the urban ecology.

YOYO'S RESULTS

- Yoyo captures over 90% of PET flows for each person who joins the sorter community (equivalent to collection rates in Germany with the deposit system).
- The sorting error rate for plastics collected by Yoyo is lower than 1%.
- At neighborhood level, collection and recycling rates are an average three times higher with the Yoyo system.



Three questions for Eric Brac de la Perrière, Founder of Yoyo

Where do you see Yoyo in a year's time? Then in five years or ten years?

Yoyo is the digital and human solution that hands out rewards to people who sort more and better to offset the environmental impact of what they consume.

In the space of one year, Yoyo has proved that resolutely positive ecology can double the amount of plastic recycling in 30 French cities, and slow the flow of pollution. In five years' time, everybody in France will have access to a Yoyo project close to home. In ten years' time, the Yoyo rewards platform will be used by a large section of the population and by numerous businesses and cities that want to offset their impact and massively reduce their collection and recycling costs.`

Is it really possible to achieve 100% recycling for plastics?

Yoyo is already working with 5,000 French families who are achieving 100% plastic recycling. Daring to reward people and providing 100% traceability right across the circuit is a great way to encourage people and earn their trust. Our challenge is to grow our community so that we can reach as many people as possible.

What does working for ecology mean to you?

It's about creating a new ecosystem that will mean consumption has zero negative environmental impacts. Ecology is real when it enables as many people as possible to act quickly and simply to change the situation. Ecology is also a matter of building and using easily understood indicators to measure impacts, making it simpler to adapt to changes in consumer behavior.

To find out more:

Website: yoyo.eco
Facebook: @Yoyo.eco
Contact: contact@yoyo.eco

PLASTIC BANK: LAUNCHING SOCIAL PLASTIC® REVOLUTION

David Katz
Founder and CEO, Plastic Bank

Haïti

David Katz is the founder and CEO of Plastic Bank, an organization that is revolutionizing the recycling industry in its pursuit to stop ocean plastic. David is the winner of Entrepreneur Organization's Global Citizen of the Year award, the recipient of the United Nations Lighthouse Award for Planetary Health, and recipient of the Paris Climate Conference Sustainia Community Award.

KEYWORDS
• SOCIAL PLASTIC
• SOCIAL FRANCHISE
• POVERTY
• DIGITAL PLATFORM

Plastic Bank is working to stop ocean plastic while reducing poverty. By enabling the exchange of waste plastic for money, goods, or blockchain-secured digital tokens, Plastic Bank reveals the true value of the material, making it too valuable to throw away. This empowers recycling ecosystems around the world, driving responsible economic development in underprivileged communities and reducing the flow of plastic into our oceans.

Most ocean plastic comes from developing nations where no recycling infrastructure exists. Plastic Bank constructs this infrastructure and pays a Social Plastic® premium rate for plastic waste, ensuring that a consistent, liveable income is earned by its collectors. Increased incentives for recycling motivate communities to take action against their everyday pollution. Plastic Bank also enables local entrepreneurs to set up and operate their own Plastic Bank branch as a fully supported franchise.

Plastic collected at Plastic Bank branches is recycled and sold as Social Plastic® to organizations who want to create a more sustainable, eco-friendly, and socially responsible supply chain for their products. The value of Social Plastic® goes beyond the commodity price of plastic: a ladder of opportunity is created for the world's impoverished and our oceans are protected from pollution.

Using its innovative digital platform and its experience in Haïti, Indonesia, and the Philippines, Plastic Bank is creating a digital ecosystem that will allow for a worldwide, open-source Social Plastic® revolution. In the meantime, Plastic Bank continues to expand its recycling infrastructure in these regions and develop new markets, such as Mexico and Brazil.

What is the mission of Plastic Bank which wants to revolutionize the recycling industry?

We are engaging the most globally unifying opportunity in history: plastics in the ocean. The world is becoming aware of the need to act for the health of our planet. People are willing to do something, but they don't know how. In recognition of that, we are simply offering a way for every single person in the world to be a part of creating change.

Plastic Bank provides a consistent, above-market rate for plastic waste, thus incentivizing its collection. Individuals who gather plastic can exchange it for cash, blockchain-secured digital tokens, goods or services, and even tuition. We reveal the value in plastic. To do this, plastic collected through Plastic Bank is recycled and sold as Social Plastic® to companies which want to have a global impact on the environment and social welfare. This creates a closed-loop economy for plastic, reducing the need for virgin plastic production.

Currently over 2,500 Social Plastic® collectors are working in Haïti, Brazil, and the Philippines. We have already collected 3,000,000 kg of waste plastic since 2014, and our operations continue to grow exponentially.

Haïti

I came to learn that if we could change how people see plastic, that will be part of the solution. The idea came while I was attending a 3D printing seminar and I realized that a piece of 3D printing plastic was sold at 8 times the price of the primary material and that value came only from changing the shape of plastic. That is how I thought that if we manage to change the mindset on plastic, then plastic could become value.

Thanks to our digital platform and our experience, we can provide a digital ecosystem that can allow for a worldwide, open-source Social Plastic® revolution.

Once I have realized the potential of this idea, the main challenge was about becoming the person who can make the change. All the rest, I have managed to figure out.

Why did you launch Plastic Bank in Haïti?

When I started Plastic Bank in Haïti in 2014, I learned a lot about poverty, illiteracy, fear, scarcity, etc. It's a place where people fight for themselves as there's scarcity everywhere. Collaboration happened as we were able to show that Plastic Bank can create new possibilities for everyone. Perseverance was necessary to go beyond the barriers and show that we can bring value for all.

As our inaugural launch, Haïti was the testing ground for the Social Plastic® model and greatly influenced our direction today. Haïti was chosen because of its high poverty rate and immense plastic pollution problem — the majority of ocean plastic comes from impoverished regions with no disposal infrastructure. We had to navigate the challenges of creating a circular economy on an island and adapting to a new culture. With the success of Haïti, we're now challenged to adapt to urban centres like Manila, Philippines and São Paulo, Brazil, where conditions are completely unique.

Plastic Bank has developed different models in countries where its operate. How do you work locally?

In Haïti, as there are no recycling facilities, we needed to create storefronts where people can return the material. Because people cannot go to far to return the material, it is based on building and expanding infrastructure. We already have 40 stores. My view is that at least a thousand stores in Haïti will be necessary to cover the needs of the population. In order to scale quickly, we are angling to use small grocery stores and lottery centres as collection locations.

The Philippines are a mature recycling market where there are junk shops already everywhere. People can bring materials to the junk shops and get money for that. We are working with a cooperative of junk shops which represents 150 junk shops to unify them, create social franchises, improve their business platform and profitability, and give them a digital platform.

Philippines

In urban Brazil, recycling cooperatives are already trying to capture the lost value in their environment. Similar to the Philippines, we are establishing a social franchising model to improve the existing recycling infrastructure in Brazil and make it a more viable business venture for local entrepreneurs. However, unlike the Philippines, Brazil is not an island, and its citizens have different needs and cultural values that need to be accounted for.

How do you turn plastic into a currency?

We are changing the paradigm on plastic waste by monetizing it for the world. If every bottle was five euros, how many would you see on the street? Zero. What did we just prove? That the question is not the bottle: it is the value that we give to it. By turning what was once waste into a resource, it becomes a way to end extreme poverty.

There are currently 8.3 trillion kilograms of plastics on the planet. At a price of 50 cents per kilo, that represents $4 trillion value which can eradicate poverty around the world eight times over.

Plastic Bank is creating a circular economy for plastics by creating the opportunity to use plastic as money. We are providing entrepreneurial experience to the world's impoverished by providing them the opportunity to make a living through plastic collection and have access to basic goods and services.

Our social franchising model provides the ability for local entrepreneurs to set up and operate a convenience store for their community in which plastic waste is the currency. In these convenience stores, plastic collectors can buy sustainable stoves, cooking fuel, clean water, electricity, WiFi, and more. They can also send their children to school through Plastic Bank education initiatives.

How do you engage with brands which are more and more under pressure regarding plastic?

Brands can buy Social Plastic® to use in their supply chain for plastic packaging. For instance, we are providing Henkel with Social Plastic® for use in their home and beauty care products.

We are also offering the opportunity for companies to offset their plastic footprint by funding the collection and recycling of an equal amount of plastic within our ecosystem. For example, Shell is working with us to reduce their plastic footprint. We also offer plastic neutral packages to individual consumers who want to reduce their environmental impact.

Brands are awake and need to ensure that they can continue to sell products packaged in plastic, and consumers are becoming more hesitant. Social Plastic® is one of the only ways to answer this need. Brands which are using Social Plastic® can show their environmental and social commitments on their packaging.

Philippines

Haïti

One of your mission is to alleviate poverty. What are the social benefits of Plastic Bank and how do you measure your impact?

When Social Plastic® is made into new products and purchased by every day consumers, collectors and families in impoverished regions are the direct beneficiaries. Collectors earn a stable living wage and gain access to the goods and services that we take for granted in developed countries. On a bigger scale, it's about humanity coming together to be the cause and the solution. We are uniting humanity to take local actions that create global impact. Anybody can be part of the Social Plastic® revolution.

For me, the impact is about how many children are going to school, which is a direct contribution to alleviate poverty. I did not expect, when I launched Plastic Bank, that this would become one of my main key performance indicators. On the contrary, I thought that it would be volume of materials. But when I speak to plastic collectors, and especially women, they all say that the main benefit is the possibility to send their kids to school.

Of course, we also measure the volumes of materials we collect, the number of collectors who are directly benefiting from our ecosystem, the number of family members who indirectly benefit, and a wide variety of other metrics.

Plastic Bank is creating a circular economy for plastics by creating the opportunity to use plastic as money. We are providing entrepreneurial experience to the world's impoverished by providing them the opportunity to make a living through plastic collection and have access to basic goods and services.

What are your next steps?

Our priority is to scale up the project. Thanks to our digital platform and our experience with these three different models, we can provide a digital ecosystem that can allow for a worldwide, open-source Social Plastic® revolution.

We have also partnered with an organization called World Vision, an NGO supporting families of 3.2 million children every month by providing meaningful work to parents. We are currently working with World Vision to develop our entrepreneurial project as a solution to alleviate poverty.

In the long term, the aim of the company is not to make money by selling plastics, but to oversee the global plastics trade linked to Social Plastic® and even provide banking services to plastic collection businesses and collectors.

Our ambition is to let the open market determine the price of Social Plastic®, while today we have a fixed price. It will be a great success if Social Plastic® can become cheaper than virgin plastic.

IMPLICATIONS OF THE CIRCULAR ECONOMY AND DIGITAL TRANSITION ON SKILLS AND GREEN JOBS IN THE PLASTICS INDUSTRY

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KEYWORDS

- DIGITALIZATION
- CIRCULAR ECONOMY
- GREEN JOBS
- SKILLS
- COBOTIZATION
- BLOCKCHAIN

Europe's plastics industry employs 1.5 million people and its 60,000 businesses generate revenue of €350 billion. This industry is particularly impacted by the rise of the circular economy and digital transition: in addition to changing businesses' economic models, these developments also bring with them structural and workforce changes that require taking a fresh look at traditional roles and their associated skill sets. Jobs are changing in shape and content, from design to production, all the way to waste recovery. The arrival of cobotization (human-robot collaboration) and blockchain are part of this movement. Businesses and training bodies are adapting their support strategies in response to this phenomenon and growing skills hybridization.

INTRODUCTION

Public policy in recent times has encouraged development of the circular economy as a response to overarching environmental challenges and a promising source of jobs. This paradigm challenges businesses' economic models and initiates concrete changes in actors' uses and practices. Similarly, societies are being swept by digital transition, leading to changes that are sufficiently far-reaching that they require public and private bodies to prepare for changing job roles and the skill sets associated with them. Digitalization opens up new prospects for economic actors of all types in terms of organizational structure, productivity and skilling. Green jobs seem more attractive than ever as they are to be found in promising sectors destined to grow during the decades ahead. This paper seeks to identify interactions between various challenges related to the development of the circular economy, digital transition and changes in skill sets.

THE CIRCULAR ECONOMY AND CAREERS

EMPLOYMENT IN THE CIRCULAR ECONOMY

The circular economy encompasses environmentally focused activities, including remediation, that make a direct contribution to protecting the environment and sustainably managing resources, as well as peripheral activities that help to improve environmental quality. Discussions are under way at present into how to draft indicators to assess the circularity of an economy, and one such indicator is employment. This is because a move toward greater circularity can be assessed through examining the number of jobs reassigned from resource-intensive activities to activities that help to reduce resource use[1]. The jobs concerned are those that optimize use of materials (eco-design, recycling, reuse), that permit extended product life cycles (repair and repurpose, functional economy), and those that set up territorially based logistics circuits (industrial ecology, short circuits). An alternative reading distinguishes between green jobs and greening jobs[2]. The former are found in the following sectors: energy, water, sanitation, waste processing, and protection of nature and the environment.

1 Jolly, C. & Douillard, P. (2016) *L'économie circulaire, combien d'emplois ?* [The circular economy, how many jobs?], La Note d'Analyse, April 2016, issue 46. France Stratégie

2 French National Center for Monitoring Green Economy Jobs and Trades (Onemev)

PLASTICS INDUSTRY EMPLOYMENT: KEY FIGURES

Europe produced 64.4 million metric tons of plastic in 2017, generating revenue of €350 billion. Some 60,000 businesses employ 1.5 million people. In 2016, the volume of plastic recycled in Europe exceeded the quantity sent to landfill for the first time. A total of 8.4 million metric tons were recycled, either within Europe or beyond its borders.

The French plastics industry is number six in the world and number two in Europe, behind Germany. In 2018, 3,500 businesses, over 90% of them SMEs, generated revenue of €30.2 billion. Together they employ 122,000 people, mainly in production[3], but with over 7,000 involved in R&D.

In France, the plastics industry, which is structured around 23 processing techniques, struggles to recruit people with the appropriate technical skills. This applies to people with cross-disciplinary skills (logistics) and semi-skilled jobs (manual workers) but also, and more acutely, to key specialist roles in the industry: fitters, senior technical sales specialists and plastics fabricators[4]. Faced with this skill shortage, the industry has taken steps to organize training paths leading to a professional qualification certificate (CQP). There are currently 17 training modules that lead to a CQP, covering all primary business functions (design, production and maintenance, sales and back office)[5]. These training offers have to address the challenges facing companies in the industry[6] as well as helping to make the sector more attractive.

3 https://www.laplasturgie.fr/chiffres-cles-en-france-et-en-regions/
4 Observatoire de la plasturgie (2017) *Besoins de main-d'œuvre et offres d'emploi dans la plasturgie.* Année 2017
5 https://cqp-plasturgie.fr/
6 DEFI & Observatoire de la plasturgie (2017) *Etude sur l'évolution des compétences nécessaires aux entreprises et actualisation des fiches métiers cœur.* [Study of the changes in skilling needed by business and updating core role descriptions]

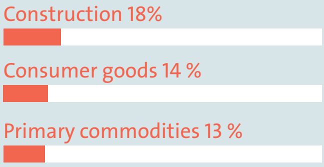
PLASTICS INDUSTRY EMPLOYMENT IN FRANCE: KEY FIGURES

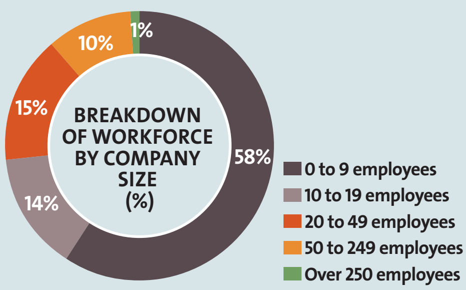
30.2 bn euros in revenue

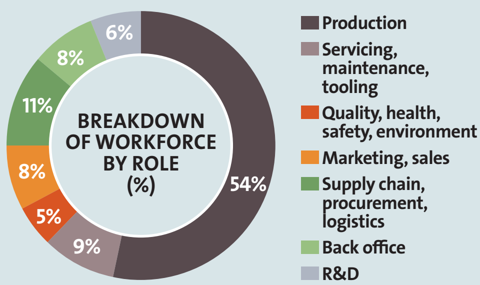
3,500 businesses

122,000 employees

PLASTICS INDUSTRY TOP 3 CUSTOMER MARKETS
(as total % of intermediate uses of plastics industry products)







Source: www.laplasturgie.fr

In other sectors, greening occupations include new skill sets to take account of environmental aspects. The green economy comprises green jobs and greening jobs, and in France these represented 3.7 million jobs between 2010 and 2014[7], or 14.6% of all of the country's jobs. The core of the circular economy comprises green activities, hiring, repairing and reusing or repurposing, and is estimated to number 800,000 FTE jobs.

Based on job creation patterns in waste management, ADEME (the French Agency for the Environment and Energy Management) judges that, on average, processing 10,000 metric tons of waste leads to the creation of one FTE when sent to landfill, three to four FTE when recovered by incineration, composting or methanation, 11 FTE when taken to a sorting center, and 50 FTE when complex end-of-life products are disassembled[8].

CIRCULAR ECONOMY: A SYSTEMIC VISION OF FLOWS THAT ALTERS THE VALUE PROPOSITION

For a business, a circular economy approach implies adopting a systemic vision of energy and raw material flows that must be closed, either internally or with the help of partners. This alters the company's value proposition and encourages it to examine other possibilities: extending operational lifespan, repair, repurpose or remanufacture. This also modifies elements of the business model: resources, skills, internal organization, value network, revenue flows and cost structure[9].

The circular economy stimulates servitization (transition from a supply of product to a provision of service) and the functional economy. Product-service systems (PSS) that deliver economic and environmental benefits also alter the structure of the value generated[10]. Once this occurs, value management skills become central. Product-oriented PSS add services such as maintenance or buyback to the product sold. This is a sales-based model that generates limited environmental benefits. Use-oriented PSS make the product available to the customer, who is then billed for each use (hires, shares, pooling)[11]. This can be used for products as common as vehicle tires. As part of its digitalization strategy, Michelin recently launched a tire hire product paired with connected services. This form of PSS tends to be disseminated via an ecosystem of associated services. For example, car-sharing leads insurers to offer per-journey contracts. The owner of a good is incentivized to organize its circularity by lengthening the time it is in use and extending its lifespan. Lastly, a result-oriented PSS makes it possible to levy a charge if the result (generally how an installation performs) conforms to the contract. This form of PSS, centered on meeting customers' needs and satisfying them, would appear to be the most eco-efficient[12].

The circular economy is characterized by creating flow loops. The closed cradle-to-cradle loop appears to be the ideal scenario, requiring cooperation and involvement from consumers and local government. For example, digital apps allow people to hand over their empty plastic bottles at recycling centers in return for secure tokens that can then be used to pay for purchases or phone plans[13]. Other projects are also breathing new life into the long-established deposit model by monetizing savings made in carbon footprints[14]. The rise of waste exchanges via digital platforms facilitates circulation of information and exchanges of materials. These services make it far cheaper for users to search for what they want, and create lower recovery and transportation costs for those generating and collecting the waste. This is a clear example of how the circular economy, delivered via digital tech, extends possibilities for sharing value.

Apps can also change how people behave. Smartphone chatbots can guide consumers to improve their waste sorting practices[15]. Virtual reality animations can help consumers gain a better understanding of certain environments[16]. These customer relational mechanisms demand skills in artificial intelligence as well as communications, skills that local government is increasingly deciding to dedicate to waste management processing.

Moving to circular economy practices forces businesses to look again at internal organizational structures. They have to adapt to the digital transition, which modifies the shape of roles and the skills needed to perform them.

DIGITAL TRANSITION AND EMPLOYMENT IN THE CIRCULAR ECONOMY

IMPACTS OF DIGITAL TRANSITION ON ORGANIZATIONS AND SKILLS

Analyses of the impacts of digital and green transitions differ according to whether the focus is on new technologies or on demand-side changes. If we assume a scenario where new technologies accelerate their penetration into businesses (Artificial Intelligence, big data, cloud, Internet of Things, emerging web-enabled markets)[17], we will see major changes in the division of work between machines

7 Commissioner-General for Sustainable Development (2015); Onemev 2014 activity report. February 2015

8 Bibliographic review: *Quel potentiel d'emplois pour une économie circulaire?*,[Job creation potential of the circular economy], Institut de l'économie circulaire, 2015

9 Peillon, S. (2017). *Les systèmes produit-service conduisent-ils à des business models plus durables*? [Do product-service systems lead to more durable business models?], 26th International Conference on Strategic Management. June 2017

10 Antheaume, N., & Boldrini, J. C. (2017). *La convergence entre gain économique et gain écologique en économie circulaire. L›expérimentation d›une innovation environnementale dans le maraîchage nantais*. [Convergence between economic and ecological gains in the circular economy. An experimental environmental innovation in market-gardening in Nantes], LEMNA. Working document 2017/04

11 Boldrini, J.C. (2016) *Le management par la valeur : une méthode pour concevoir les systèmes produit-service de l'économie circulaire* ? [Value management: a method for designing product-service systems for the circular economy?], ACFAS 2016

12 Dahmani, S. (2015). *Proposition d'un cadre méthodologique pour la gestion du processus de servicisation en entreprise industrielle: approche basée sur les risques décisionnels* [Proposition for a methodological framework for managing the servitization process in a manufacturing company: an approach based on decisional risks], thesis, Saint-Etienne, EMSE.

13 https://www.forbes.fr/technologie/comment-la-blockchain-peut-elle-lutter-contre-les-dechets-plastiques/?cn-reloaded=1

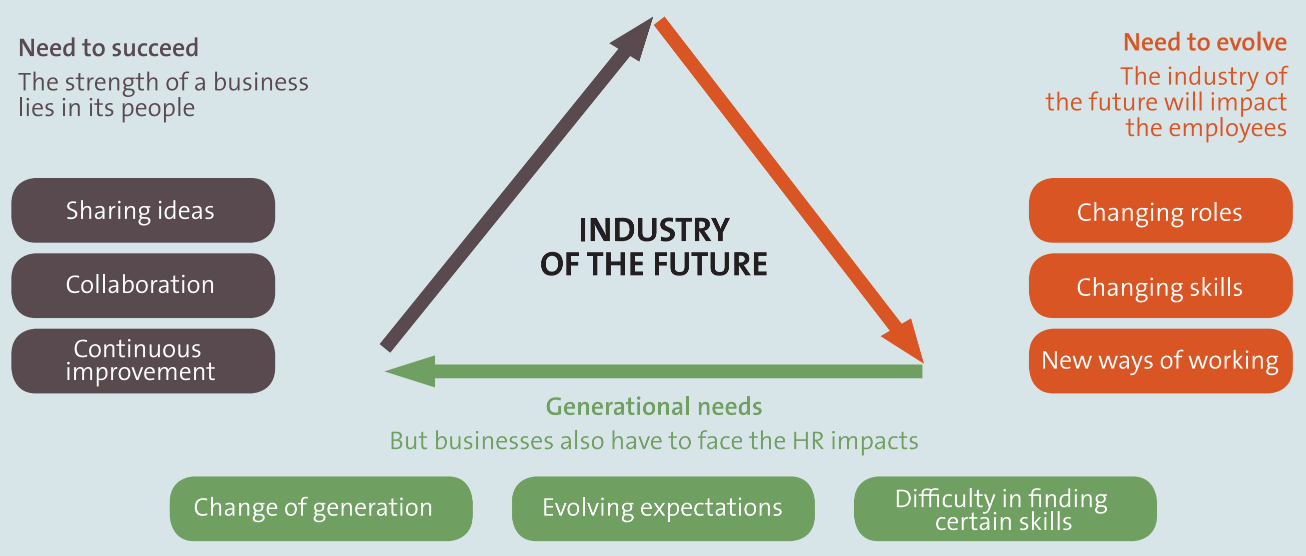
14 https://www.consoglobe.com/recycletocoin-appli-blockchain-plastique-oceans-cg

15 SMICVAL (2018) Annual report 2017

16 https://www.eco-mobilier.fr/vivre-lexperience-du-recyclage-en-realite-virtuelle/

17 World Economic Forum (2018) The Future of Jobs Report 2018

People at the heart of digital transformation



Transformation and HR challenges: change of generations, new attitudes to work (flexibility, mobility, work-life balance, quest for meaning), more third-party colleagues, need for specific skills, recruitment difficulties (industry attracting fewer new graduates).

Source: French plastics and composites industry federation

and people. Archetypally human activities – such as communication and interaction, development, supervision, consultancy, reasoned argument and decision-making – will be increasingly automated and reliant on algorithms. In the French case, this can be relativized as digitalization of the productive fabric appears to be taking place at a slower rate than in other countries[18].

For French companies[19], changes instigated by these two types of transition will be felt more in terms of transformation of tasks and skills[20] or impacts on roles and activities, rather than in the appearance of new green occupations (Figure p. 104).

DESIGN

Eco-design presupposes a life cycle analysis involving every function of the business, and will generally also reach out to external stakeholders such as suppliers, transporters and users. The circular economy reshuffles the pack, fostering the emergence of new vocations and alliances. Experiments have been run using building information modeling (BIM) to include end-of-life management and recyclability of construction materials. This means that traditional design engineering firms are integrating material recycling criteria in collaboration with property developers, and are also moving to digital platforms.

As part of strategies aiming to improve efficient use of materials, functions such as management, design engineering, R&D and design play key roles at this early stage in helping industrial processes to evolve – incorporating recycled material into a production process is no simple affair. The material must meet the user's specifications for its industrial process, but in the case of an open loop it must also meet the needs of the new user market; all of this represents multiple upstream constraints. The example of plastics is illustrative of the knowledge needed to characterize and then process different resins. A range of different skills are needed to find applications, determine compatibility (anything from vehicles to food packaging to construction) and obtain the necessary approvals from certifying bodies. Bioplastics require collaboration between experts in chemistry, biotechnologies and electronics. These same skills also make it possible to find downstream recycling solutions for the material.

COBOTIZATION

Whereas automation supposes a transfer of knowledge and expertise from operator to system, cobotics provide operators with assistance from a robot they can interact with. Today, this involves pooling skill sets between people and machines. Applications include tele-operation (remote collaboration), collaborative co-presence (human and robot share a workspace), co-manipulation (the operator directly manipulates the robot to accomplish a task, for example, providing greater force for handling heavier loads), or even exo-manipulation (a human wears an exoskeleton that

18 Gaglio C. & Guillou, S. (2018) *Le Tissu Productif Numérique en France* [France's Productive Digital Fabric], OFCE Policy brief 36, July 12.

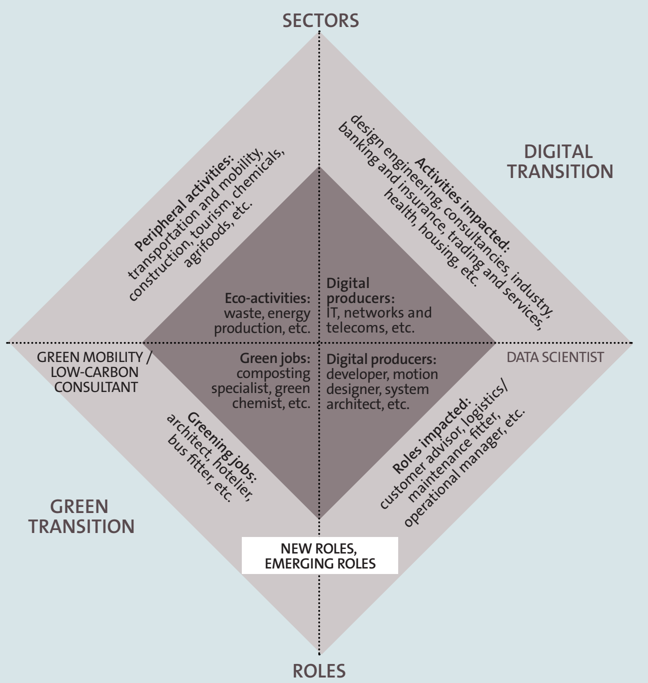
19 MEDEF (2017)

20 Marin, G., & Vona, F. (2018). *Climate policies and skill-biased employment dynamics: evidence from EU countries* (No. 2018-23). Observatoire Francais des Conjonctures Economiques (OFCE).

reduces efforts required but provides no directional guidance). The challenge of tele-operation lies in the way that operators at the controls perceive the task performed by the robot[21]. At a waste sorting center, tele-operated sorting enables operators to work from a touch-screen in a cabin, away from the sorting belt, after an initial fully automated sorting operation. Sorting waste such as plastic bags still demands a combination of a three-step process: hand sorting for large film plastic, ballistic separator for other films, and a final optical sorting. The impact this has on workstations has yet to be studied in detail, and there remain unanswered questions for specialists in ergonomics in terms of the physical constraints on operators, particularly regarding exoskeletons.

21 Moulières-Seban, T., Bitonneau, D., Thibault, J. F., Salotti, J., & Claverie, B. (2016). Cobotics: an emerging cross-disciplinary domain of interest to ergonomics, Congress of the French-Language Society of Ergonomics.

Sectors and roles in France most impacted by green and digital transitions



Source: MEDEF, 2017

LOW-TECH ANSWERS TO DIGITAL LIMITATIONS

Automation can be limited by the complexity of certain tasks. In several recycling processes, operators performing hand sorting become more efficient than the machines. For textiles, the first sorters were women, who were accustomed to assessing the quality of a fabric and the degree of wear in an item of clothing. As with plastics (box on this page), hands and eyes sometimes remain the best tools for abstracting recoverables from an input, as well as adapting easily to the variability of situations.

LOW-TECH SOLUTIONS ARE THE MOST EFFICIENT FOR SORTING PLASTICS

Several years ago Actes, a disability-friendly company operating in Bordeaux and the Basque country (France), began to diversify the range of materials it recycles, and it now also processes disposable plastic cups made from polystyrene and polypropylene. A manual pre-sort and material separation process using buoyancy was designed in collaboration with the University of Bordeaux. The company boss was trying to create as many manual jobs as possible, seeking to turn on its head the industry's rush to automate. He looked at experiences from other material recovery industries, paper in particular, that showed how manual sorting could be more efficient than automated processes.

After a year's training and practice at the sorting table, Franck and François have learned how to tell the difference between polypropylene and polystyrene resins. They look at a number of material properties (color, thickness, texture, breakage patterns) to quickly identify the product being sorted. They work more efficiently than any automated machine and can also sort the polylactic acid (PLA) cups that are increasingly common.

Purity rates can reach 100% when waste producers run pre-sorts correctly. This is the result of an end-to-end approach: sorting and recycling are simply stages in a recovery process for a material that had a very short life. Upstream, the waste producer was well aware of the importance of sorting. Downstream, a simple machine is used to provide plastic pellets to traders. Above all, the machine is also a tool for employee upskilling.

For sorting of plastics, optical recognition still struggles with new bio-sourced materials. Human input is not yet irreplaceable, and a number of secondary manual sorting posts remain[22].

BLOCKCHAIN

Of the many technologies emerging in the industry, blockchain is emblematic of digital transformations and the rise of the circular economy. This certification system by a virtual third-party[23] runs the risk of being disruptive to certain sectors of activity[24], in particular to those whose activity is based in some way on certified services or traceable products (energy suppliers, extractive industries, recyclers). Large numbers of trials are running to test these

22 http://www.smitred.com/fr/content/le-tri-optique

23 https://www.industrie-techno.com/les-promesses-de-la-blockchain-pour-l-industrie.49239

24 https://blog.d2si.io/2017/06/01/competences-metiers-blockchain/

markets, a process that requires businesses to integrate strategy, marketing, sales and technical skills[25]. This is about appropriating the technology and identifying the challenges: avoiding disintermediation in your own market and identifying new uses. For example, an energy generator must be able to pick up on emerging practices encouraged by a secure and transparent technology (consum'actors, arrival of small suppliers)[26]. In terms of recycling, blockchain can enable real-time trust and reputation systems[27].

Blockchains use existing skills (coding, security, network management) to deliver new applications. Data engineers, distributed register architects and specialist project leaders are the new figures leading this transformation. Distributed register architects play a key role, ensuring that the client's demands are properly translated into uses of blockchain. This is a skill that remains relatively rare.

It is thought that millions of jobs worldwide will be lost to machines. In 2022, the share of total work hours performed by humans will fall to 58%, with machines performing the other 42%, up from 29% in 2018.

Setting up a blockchain in recycling also requires suitable logistics, which is something that ties together the sector's traditional roles with the new uses (tracking the filling of containers and optimizing collection rounds, identification of waste and traceability)[28]. Logistics roles become levers for improving the environmental performance of the recycling chain. Today we still find that 25% of journey distances are run by heavy vehicles that return empty. Haulers and logistics chain designers need to deliver improvements in terms of pooling[29]. The business workplace trainer teaches drivers to drive in a more environmentally friendly way, and might in future be assisted (or maybe competed with) by in-vehicle assistance systems for eco-friendly driving[30]. In reverse logistics systems, the pick-up point becomes the starting point for a new recycling loop. The internet of things makes it possible to collect and prepare recovery processes optimally[31].

25 Charue-Duboc, F., & Gastaldi, L. (2017). *Le pilotage des processus d'innovation amont-Vers de nouvelles modalités de couplage entre technologies et usages* [Upstream management of innovation processes - toward new technology-use pairings], Revue française de gestion, 43(264), 23-42.

26 Stavenhagen, P. (2016) *La blockchain: Une opportunité pour les consommateurs d'énergie* ? [Blockchain: an opportunity for energy consumers?], study for the North Rhine-Westphalia consumers' association, Düsseldorf. July 2016

27 European Parliament resolution on distributed ledger technologies and blockchains: building trust with disintermediation http://www.europarl.europa.eu/sides/getDoc.do?type=MOTION&reference=B8-2018-0397&format=XML&language=EN

28 https://www.infohightech.com/du-diamant-au-recyclage-comment-la-blockchain-peut-conduire-des-entreprises-responsables-et-ethiques/

29 Onemev (2018) Activity Report 2017

30 https://www.bnpparibascardif.com/-/big-data-drives-environmentally-friendly-and-sustainable-transport

31 https://lesclesdedemain.lemonde.fr/dossiers/dechets-de-l-energie-a-recycler_f-208.html#pdvLcdd

TRAINING CHALLENGES

IMPACTS OF DIGITAL TRANSITION ON SKILLS

The impacts of digital transition are massive and felt across all sectors of the economy. It is thought that millions of jobs worldwide will be lost to machines. In 2022, the share of total work hours performed by humans will fall to 58%, with machines performing the other 42%, up from 29% in 2018. New roles will emerge, more suited to the new division of labor between humans, machines and algorithms: specialists in machine learning and artificial intelligence, big data, experts in automation, data security, customer experience and human-machine interaction, robotics engineers and blockchain specialists. In manufacturing, machines generate vast datasets that are collected, exploited and prepared by engineers for operators. For example, extruders and machines for printing, gluing and spooling plastics can operate continuously while simultaneously generating several gigabytes of data daily, data that will be used for monitoring and predictive maintenance[32].

This will in turn lead to hybridization of skills and roles. Digital skills will find their way into roles that were originally non-scientific (marketing, design, etc.), whereas other technical roles will require additional skills of a more cross-cutting nature (social, creative, etc.)[33]. These mutations, combined with rapid changes of economic models, destabilize skills bases. Businesses can then either adapt via learning and knowledge engineering strategies, or by calling in outside resources via recruiting new permanent staff, temporary staff or freelancers. Such changes demand matched training offers, with some of the skill sets to acquire being spread across very different industries. In the future, advanced engineering schools will embed digital advances within their syllabuses (box p. 107).

Transformations impacting employment types and how they are organized will lead to more frequent changes of job and task. Training methods will also evolve toward a peer-to-peer model, via platforms or augmented reality, allowing people to acquire the skills they need as and when they need them. However, not all employees within an organization will necessarily be treated equally, if only because some will be digital natives and others not. People occupying the most-impacted posts will have the greatest need for upskilling, but they risk being disadvantaged in favor of those occupying roles judged strategically important[34].

32 learning by experience applied to a machine

33 CEREQ & France STRATEGIE (2017) *Vision prospective partagée des emplois et des compétences. La filière numérique. Rapport du Réseau Emploi Compétences.* [Joint future prospects for jobs and skills. The digital indistry. Réseau Emploi Compétences report], June 2017

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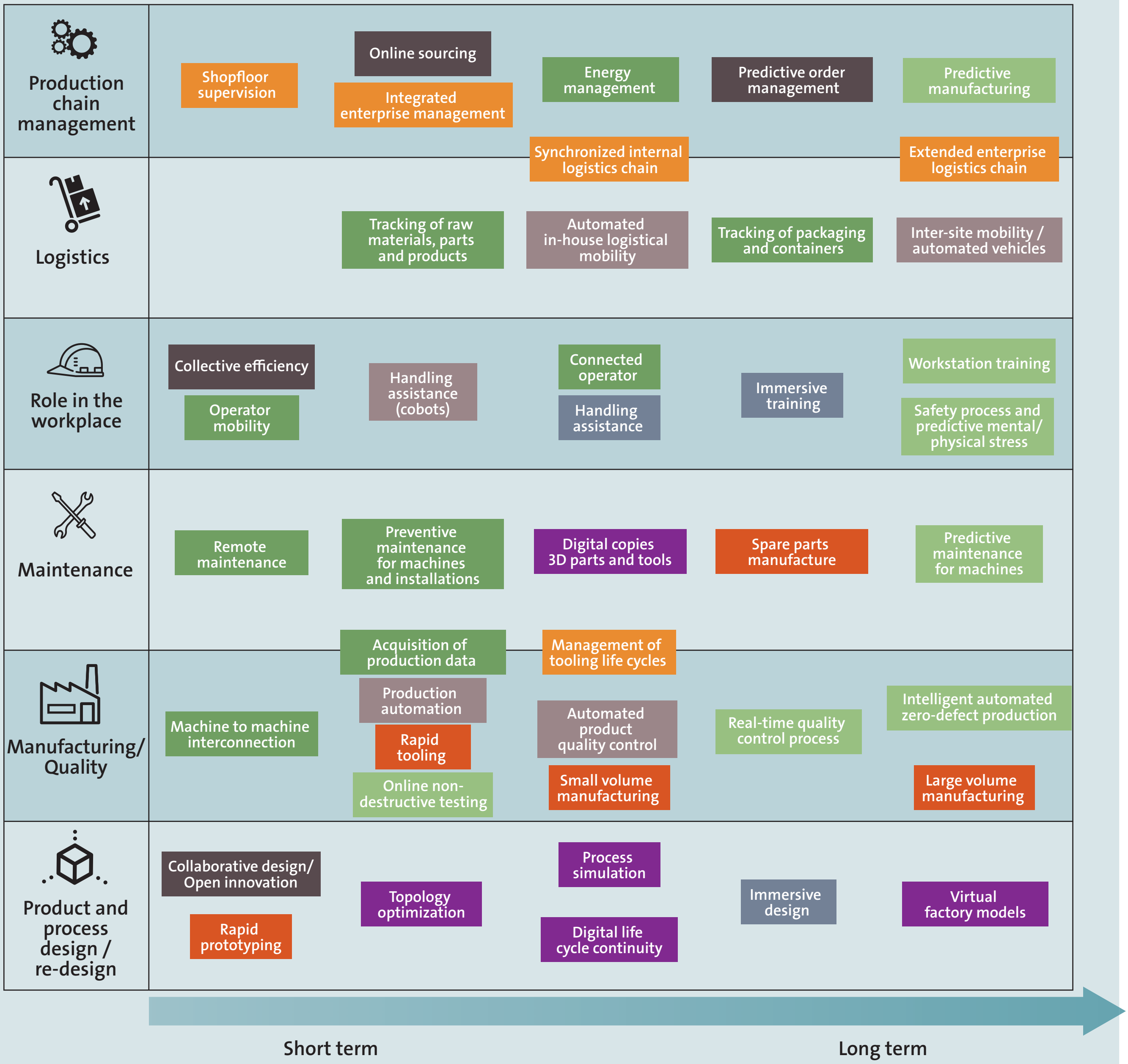
How plastics industry businesses are being transformed by digital



TECHNOLOGIES FOR THE INDUSTRY OF THE FUTURE

- Digital simulation / 3D
- IoT
- Management tools
- Virtual and augmented reality
- Robotics
- Collaborative tools
- Additive manufacturing
- Big data / data analytics

Every business has its own pathway to the future. Digital transition brings multiple opportunities. Businesses will seize those that deliver the most added value to their activity, working in ways that encourage open and collaborative innovation to reach the goal faster.

Source: French plastics and composites industry federation

Virtual reality technology in industry 4.0.

THE IMPACTS ON SKILLS IN THE CIRCULAR ECONOMY

The circular economy stimulates the appearance of new roles, new skills and new combinations of existing know-how[35]. Its activities are more labor-intensive but this should be a transitional situation with the rise of automation and robotization already under way in the waste sector. Job losses at automated sorting centers mainly concern sorting operator posts and are not compensated for by the number of new posts created for technicians[36]. And although the level of educational attainment among people employed in the green economy is trending upward (20% of workers are unqualified, 33% have a basic vocational qualification), climate policies tend to favor qualified professionals and technicians over manual workers. Faced with this phenomenon some employers are adopting upskilling strategies, soft skills included. SMICVAL, a municipal waste treatment authority in southwest France, has upskilled its waste drop-off center staff to become recovery staff with responsibility for sorting, repairing and returning used items to use.[37] Such a move requires the acquisition of a range of human, diagnostic and repair skills, fields that are also promoted by businesses from the social and solidarity economy. SMICVAL achieved a 50% upskilling rate in 2017. In a related domain, ancillary roles such as machinery maintenance could also be developed to allow for operator upskilling. The CNAM, a French high-level engineering school, now includes green jobs among its training offers.

TRAINING IN DESIGN ROLES: FROM CUTTING UP PLASTIC PELLETS TO MODELING THE REAL WORLD

The training for engineers offered at Arts & Métiers Paris Tech reflects the increasing importance of digital. It combines knowledge and understanding of physical phenomena with digital technologies' ability to represent and model those same phenomena. Students work on a digital "reality twin": the virtual component enables them to reproduce part of the real (the physical model), to represent complex systems and run different scenarios. For example, it is possible to change the settings of a motor or machine in operation to observe the resulting changes in physical and virtual behavior. Physical-digital pairing speeds up problem-solving as digital and physical approaches were previously separate.

Teaching methods are inspired by the world of gaming. A computer, mouse, camera (to film reality) and augmented reality goggles (to map data) allow students to step inside the motor, thanks to immersive technologies. These are technologies that are also used in professional environments. The idea is to gain better insights into phenomena, to have inputs about the same representation from several different participants. Skills that were previously exercised separately become complementary in real time. The department of mechanical engineering and design is developing design tools and methods that take account of the phases of a product's life. This whole-life approach makes it possible to run and assess different scenarios for uses and tasks, looking at issues such as the technical, economic and environmental performance of recycling scenarios and making it possible to decide on the best technology mix from a very early stage.

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Editor-in-Chief: Nicolas Renard, Director of Foresight, Veolia Institute

Deputy Editor-in-Chief: Fanny Arnaud, Program Director, Veolia Institute

Publication Director: Dinah Louda, Executive Director, Veolia Institute

Issuing Body:
Field Actions Science Reports (FACTS) is published by the Veolia Institute. EISSN: 1867-8521

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Designed and produced by: increa
Cover: Veolia Graphic Studio

Printed in France
with vegetable-based inks by an environmental printer (a member of Imprim'vert) on chlorine-free paper from well-managed forests and other controlled sources, certified in accordance with the standards of the Forest Stewardship Council.

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"Moving plastics from the disposal society into the circular economy is the only sustainable way forward."

Harvey Fineberg
President of the Gordon and Betty Moore Foundation
and Member of the Veolia Institute Foresight Committee

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