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**Electronic version**

URL: <http://journals.openedition.org/factsreports/5071>

ISSN: 1867-8521

**Publisher**

Institut Veolia

**Printed version**

Date of publication: 1 March 2019

Number of pages: 6-11

ISSN: 1867-139X

**Electronic reference**

Philippe Chalmin, « The history of plastics: from the Capitol to the Tarpeian Rock », *Field Actions Science Reports* [Online], Special Issue 19 | 2019, Online since 01 March 2019, connection on 15 October 2019. URL : <http://journals.openedition.org/factsreports/5071>

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

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## 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 21<sup>st</sup> 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 20<sup>th</sup> century, reached its peak some 100 years later and whose eradication will be one of the major challenges of the 21<sup>st</sup> 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 20<sup>th</sup> 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.

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

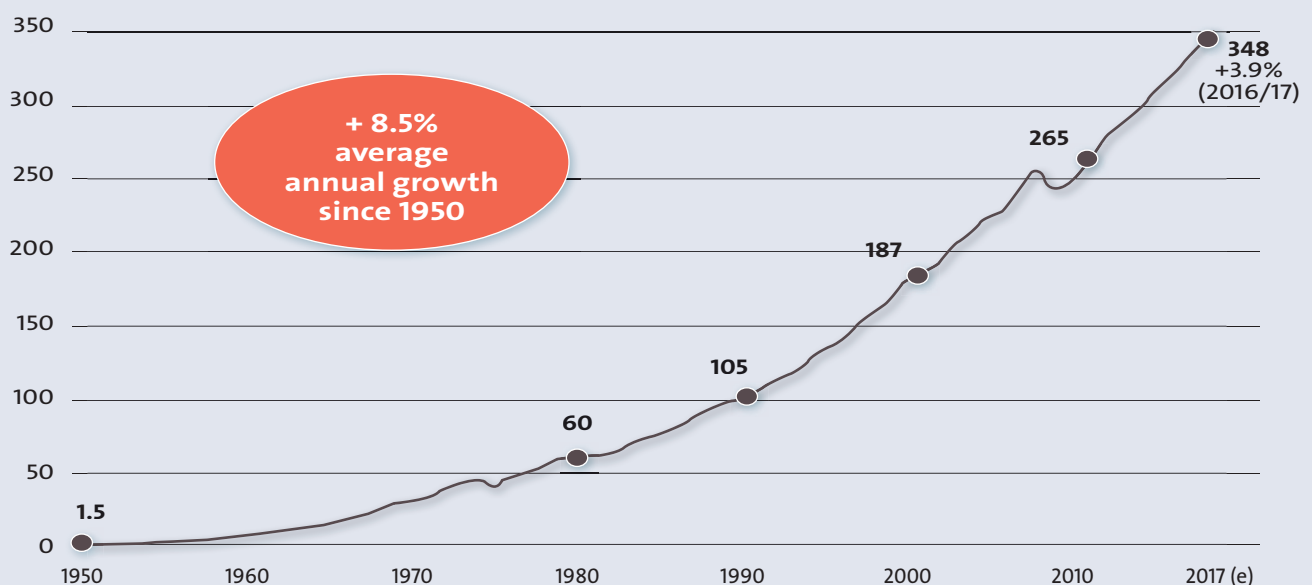
engineer Giulio Castelli molded the first plastic draining rack. Ten years later, Roland Barthes devoted one of his “Mythologies” to plastic: “Plastic has climbed down from its pedestal, it is now a household material [...] the whole world can be plasticized.” And so it quickly was: plastic even had 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.

*“Product invented in the early 20<sup>th</sup> century, reached its peak some 100 years later and whose eradication will be one of the major challenges of the 21<sup>st</sup> 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 million 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

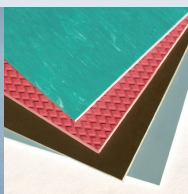
have historically been oil groups (Shell, Aramco, etc.), and chemical companies that often separated their heavy and fine chemicals businesses. It is a very capital-intensive business in a particularly unstable environment, whether for the upstream market (oil and gas) or the downstream markets (commodities). 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.



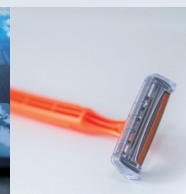
### PLASTIC BOTTLE

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.

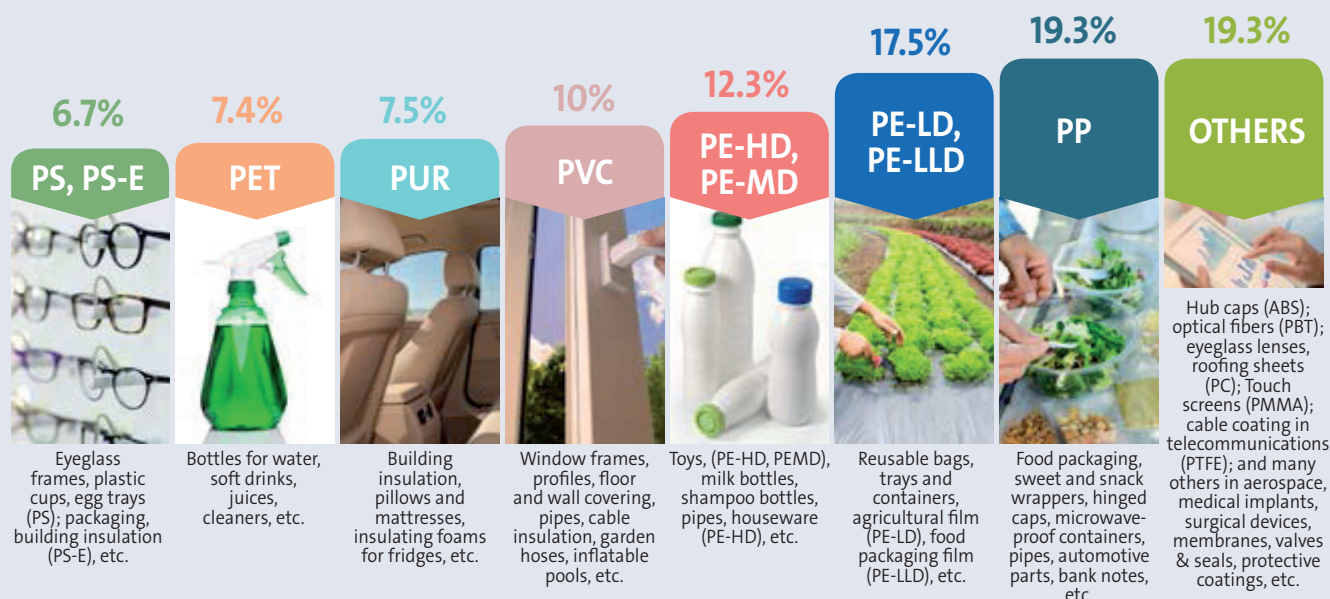
Packaging is still the main outlet for plastics (150 million metric tons) followed by building and construction (60 million metric tons, accounting for 40% of use in the European Union and as much as 46% in France), textiles (55 million metric tons), consumer goods, the automotive sector and electronics. 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

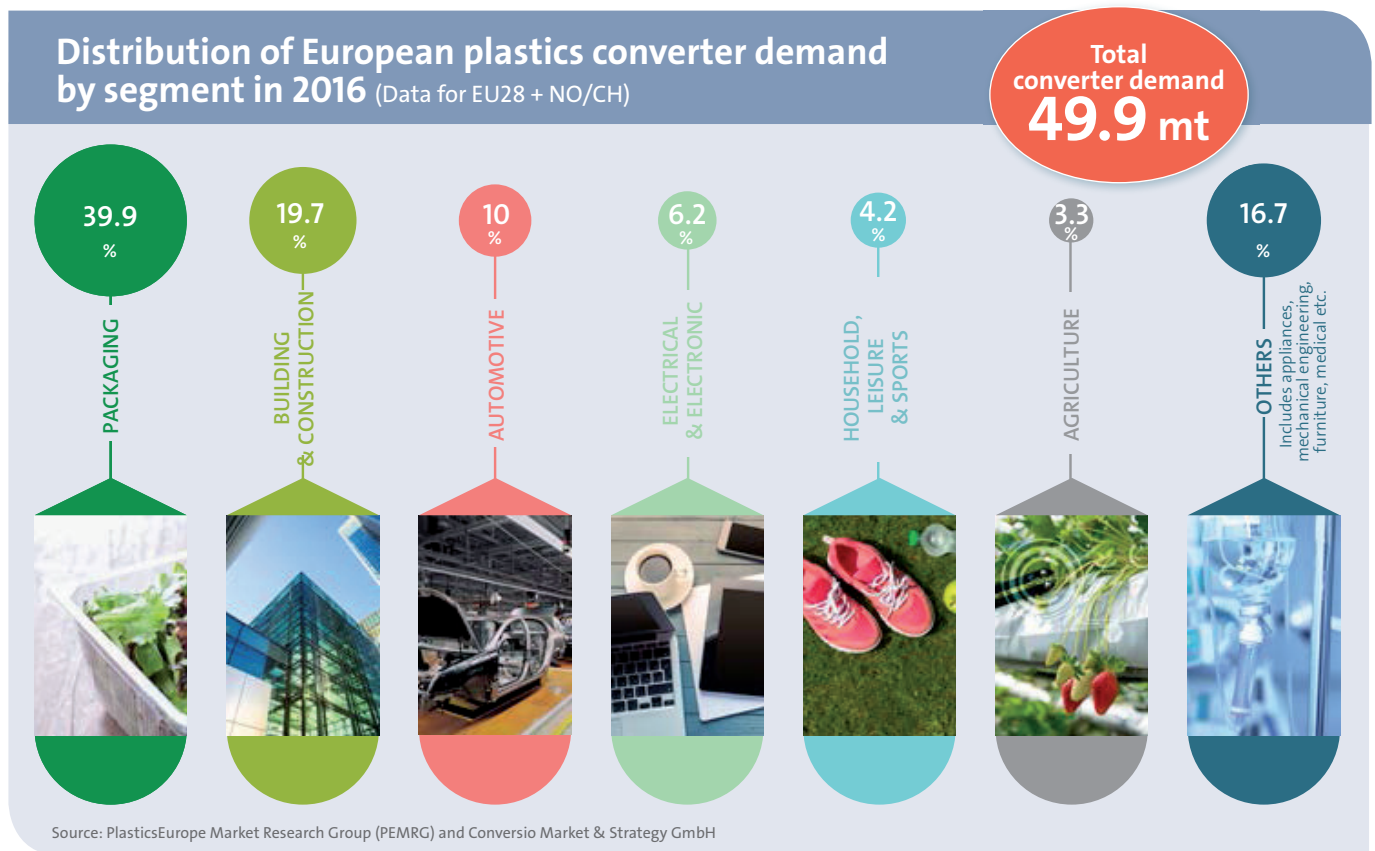
## European plastics converter demand by polymer types in 2016

Data for EU28 + NO/CH



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."<sup>1</sup>

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 21<sup>st</sup> 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.

<sup>1</sup> *L'Obs*, May 2018