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PLASTICS RECYCLING WORLDWIDE: CURRENT OVERVIEW AND DESIRABLE CHANGES

Woldemar d'Ambrières
Strategic Projects Director, Veolia



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.

Woldemar d'Ambrières is Strategic Projects Director at Veolia, where his responsibilities include coordinating the international strategy for recycling and recovering plastics. He was previously part of Veolia's internal audit team and before that a project manager with Veolia in the United Kingdom. He is a graduate of France's École Polytechnique.

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 oceans¹. 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 2017². This growth is set to continue, driven in large part by the demands of the Chinese and Indian middle-classes; demand may double by 2050³.

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 recycled⁴ 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 oceans⁵, 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

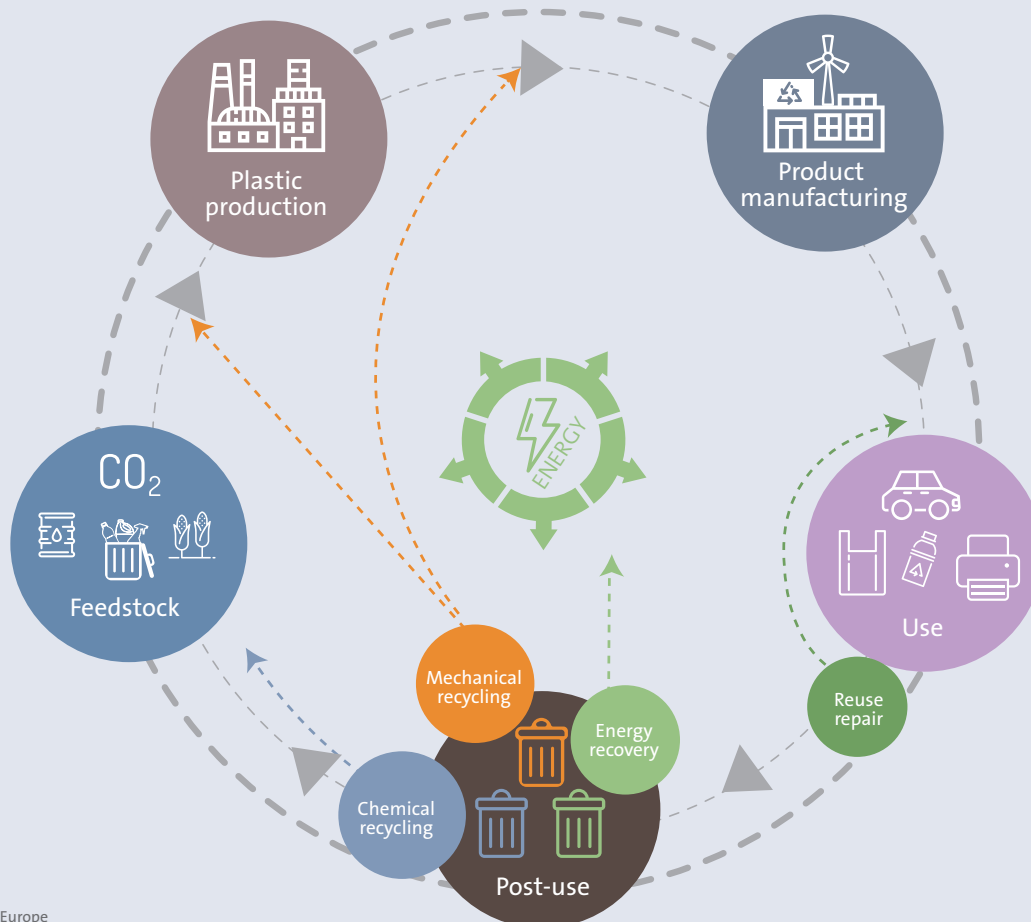
CURRENT SITUATION: COMPLEXITIES AND DISPARITIES IN PLASTIC WASTE MANAGEMENT

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.

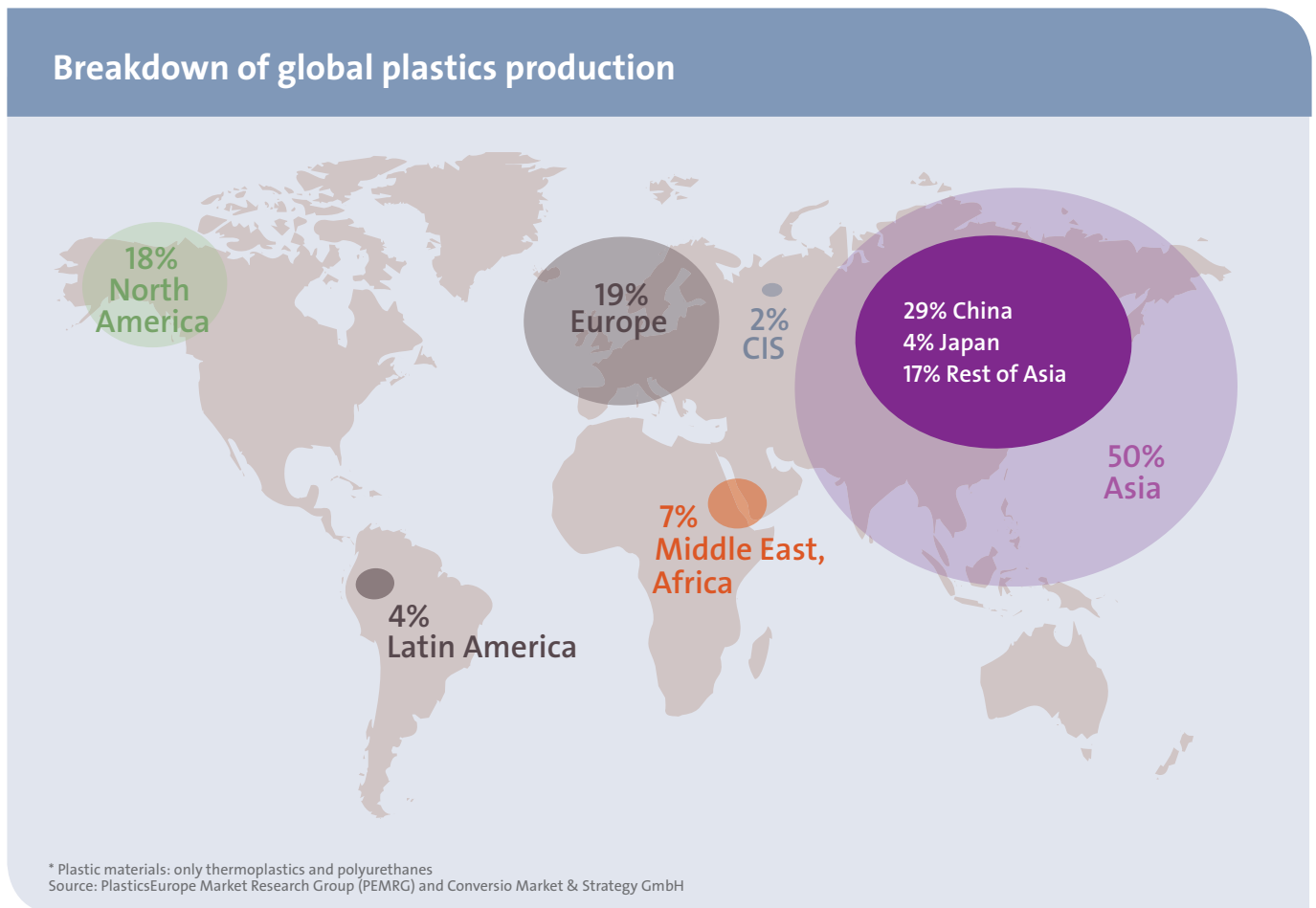
Take the example of a bottle of mineral water. The plastic will come from a petrochemical PET producer, Indorama for example, and then goes to a preformer to create a preform, an intermediate stage in the manufacture of the bottle. The preform is then blown into a bottle in a mold, and only then does 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%).



**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.

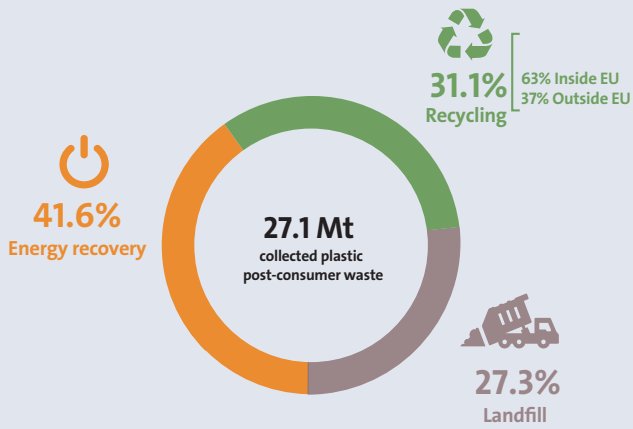
These organizations are used to finance some of the costs involved in collecting and sorting plastic waste. Funding generally comes from suppliers – producers and retailers – or is raised from consumers via green levies. This allows externalities relating to end-of-life management to be re-internalized 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

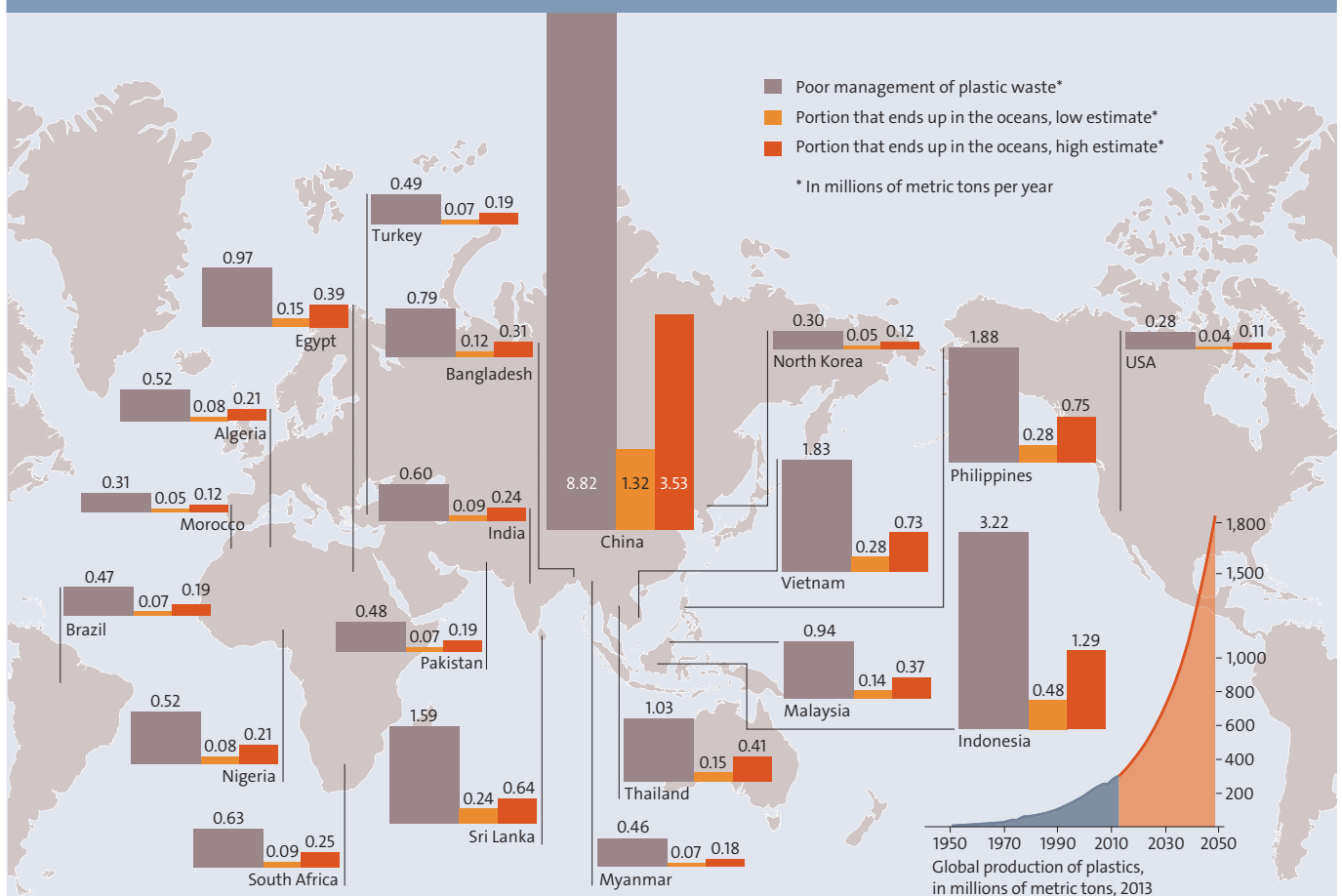
Industrialized developing economies are generally characterized by inadequate waste management infrastructure. Collection is not systematic and a large portion of household and industrial waste continues to be dumped at numerous unofficial and unregulated sites. Informal networks tend to be well developed 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



Cc-by-sa petraboekmann.de / Atlas de l'océan 2018 | source: Grida / Jambeck

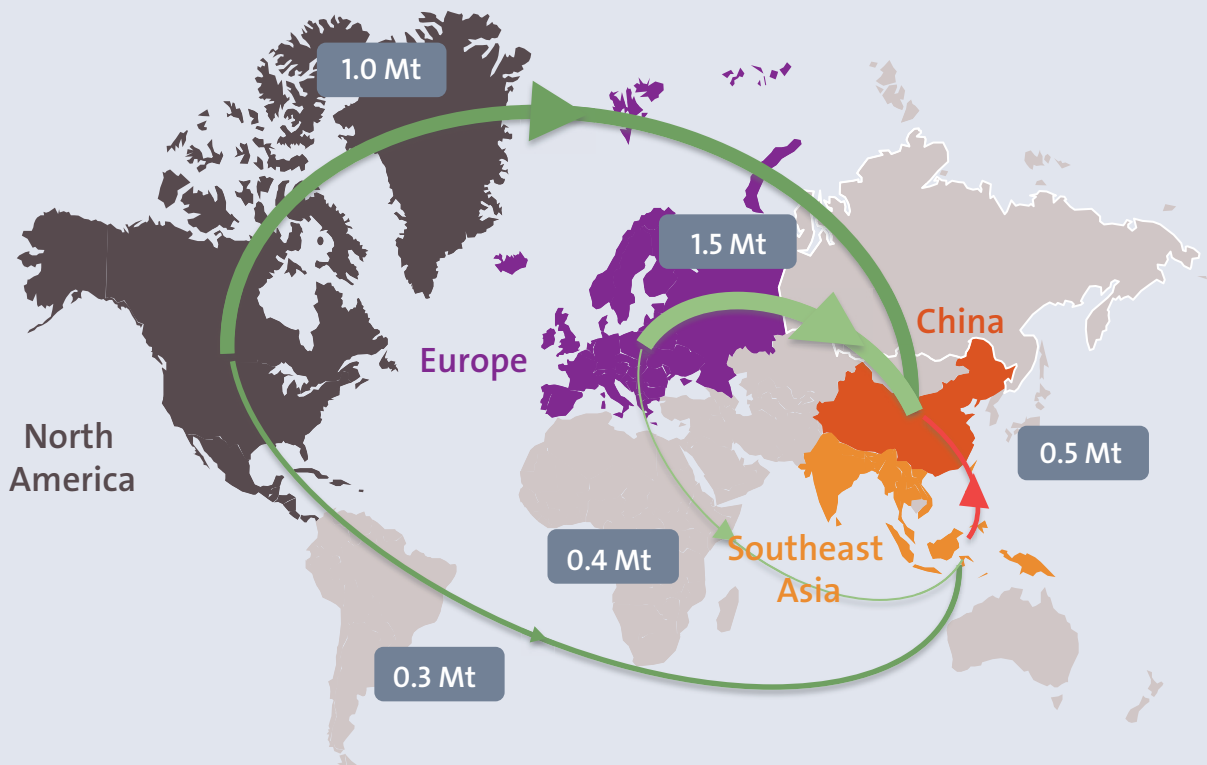
**WHERE ARE PLASTICS RECYCLED:
LOCAL RECYCLING AND INTERCONTINENTAL FLOWS**

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.

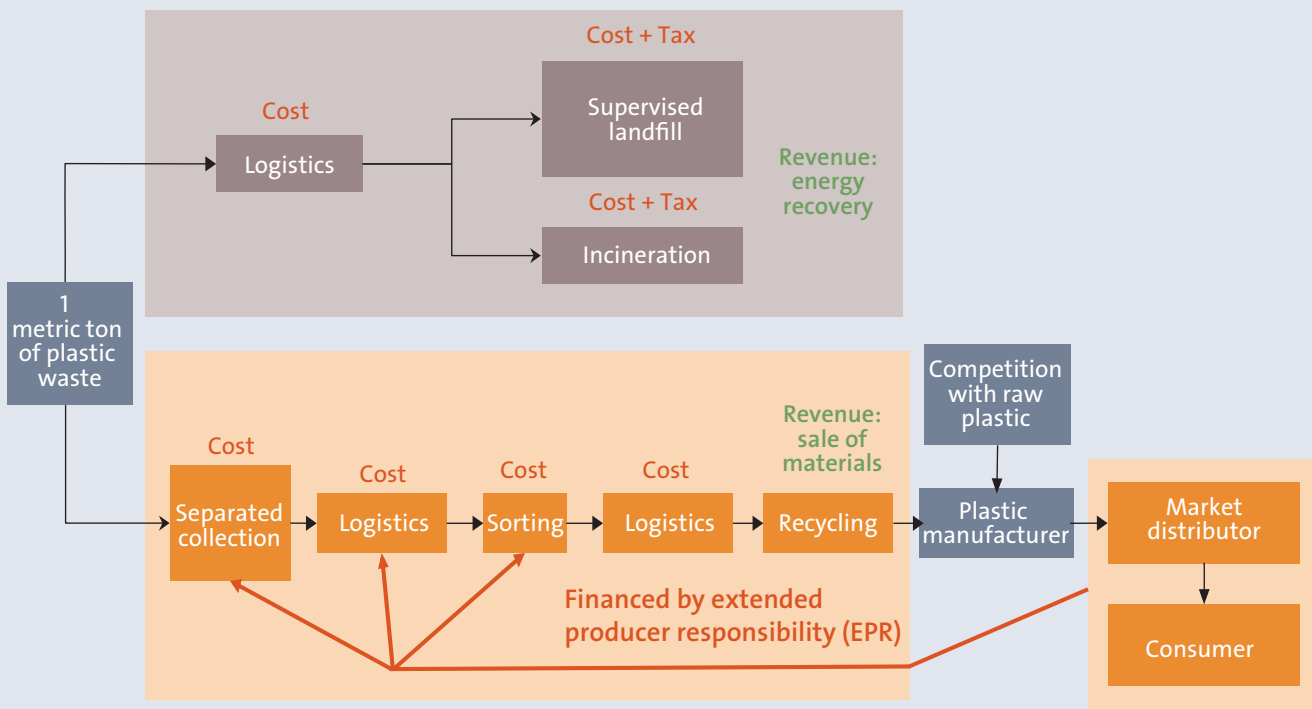
Recycling plastics also leads to significant reductions in atmospheric emissions of CO₂, because using recycled plastic avoids emission of an amount equivalent to that generated during production of raw plastic (box p. 20).

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

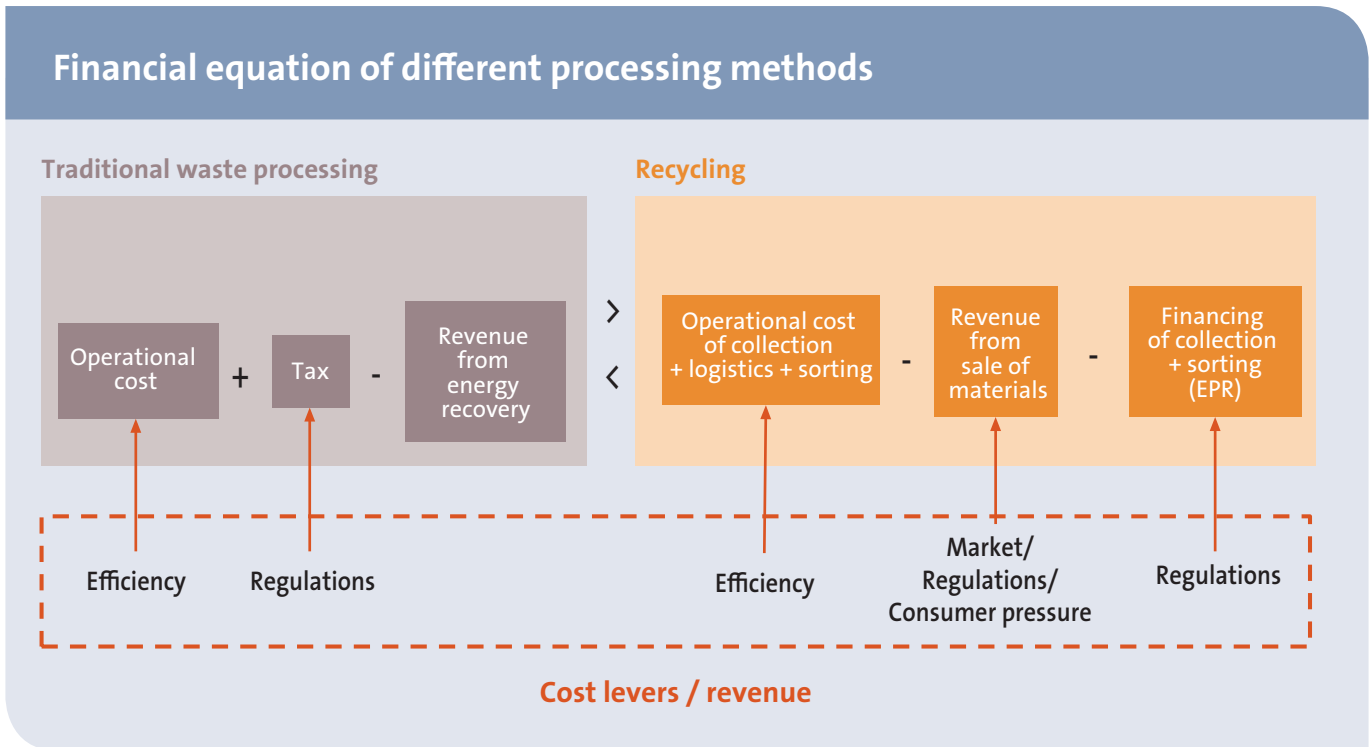
Developing recycling also fosters local growth by re-internalizing employment within a territory. Typically, a plant producing about 50,000 metric tons of recycled plastic will employ around 30 people. This is significantly

Plastic material flows to different processing methods

Traditional waste processing



Recycling



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.

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.

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.

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 CO₂ 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:

$$\text{Net GHG emissions (metric tons of CO}_2\text{e/ metric tons of plastic)} = \text{Actual GHG emissions (1) - Credits (2)}$$

CO₂e = CO₂ equivalent

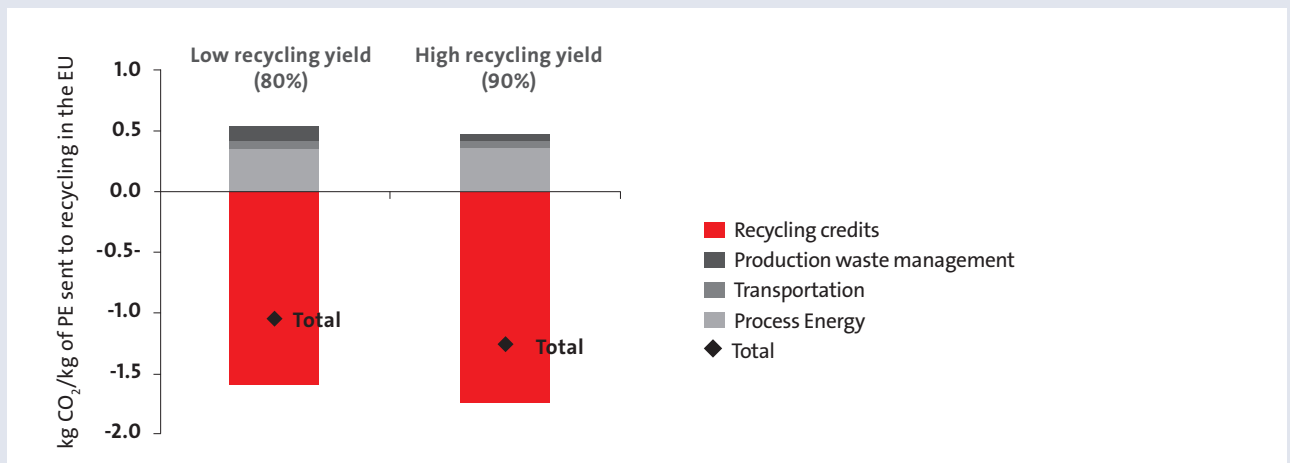
- (1) **Actual** emissions are the sum of direct emissions relating to transportation and energy use during processing, and processing rejects in the case of recycling. Actual emissions vary according to the type of polymer processed, the distance raw materials are transported, the quantity of energy 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 CO₂e/kg PE.
 - (2) GHG emissions avoided thanks to recycling are shown in red and are equivalent to approx. 1.5-1.8 kg CO₂e/kg PE.
- Net emissions are the difference between the two, a net saving from recycling of 1-1.3 kg CO₂e/kg.

Similarly, a calculation is made to determine net emissions from incinerating PE using current technologies: the energy recovery benefits (-2 kg CO₂e/kg) do not sufficiently outweigh the environmental impact (3 kg CO₂e/kg), i.e., surplus emissions of 1 kg CO₂e/kg.

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



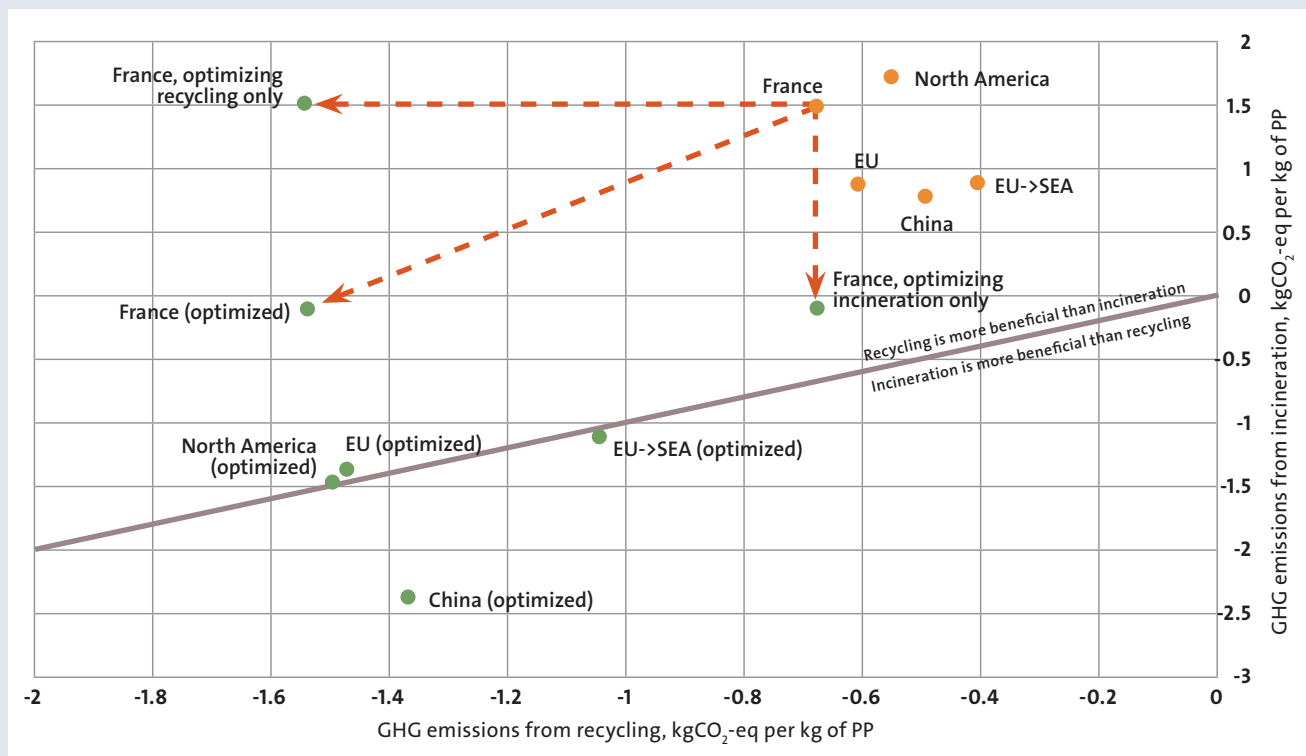
Life cycle analysis demonstrates that recycling is always the most environmentally friendly option with current processing technologies, whether processing PP/PE or PET, in France or Asia, irrespective of whether the energy performance is low or high (assuming use of current incineration facilities). 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.