IFPEN POSITION PAPER

What regulatory framework for a rational, effective and durable plastics recycling sector?

Innovating for a low-carbon and sustainable world

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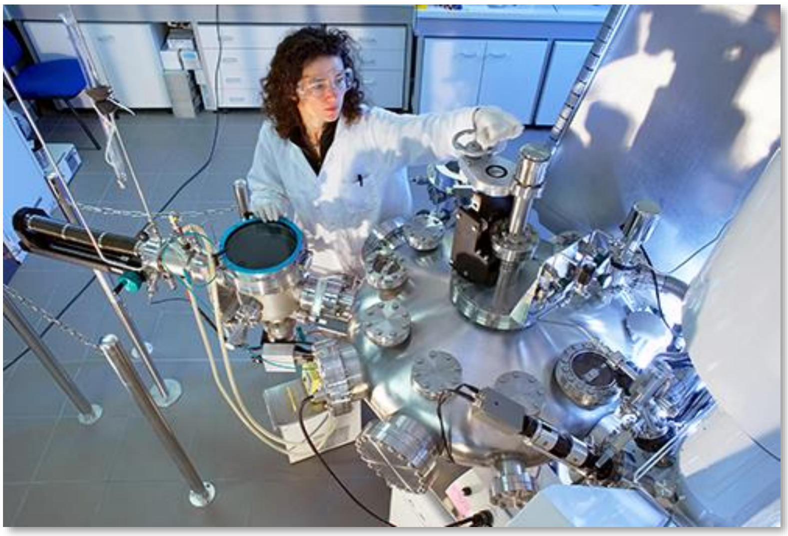
IFP Energies nouvelles

IFP Energies Nouvelles (IFPEN) is a major public research and training player in the fields of energy, mobility and the environment. From scientific concepts in basic research to technological solutions in applied research, the Institute's activities revolve around innovation, based on four key priorities: climate, environment and circular economy; renewable energies; sustainable mobility; responsible oil and gas.

IFPEN's work focuses on providing solutions to the challenges facing society and industry in terms of energy and the climate, for the benefit of the green transition. IFPEN's own graduate engineering school, IFP School, trains future generations to take up these challenges.



Key messages

The constantly increasing demand for plastics poses two major challenges:

- The impacts associated with plastic production and plastic waste,
- The widespread use of fossil resources.

Improving plastic waste end of life is a key issue that relies on the three levers inherent to a circular economy: "Reduce, ReUse and Recycle".

Plastics recycling enables us to reduce recourse to fossil resources for plastics production, at the same time making maximum use of the waste generated. It is therefore one lever available to us to address these two challenges.

Today, most recycled plastic is derived from mechanical recycling. However, while the technique has been well perfected, it nonetheless has limitations in terms of its implementation: it is aimed at homogeneous plastic waste composition, it does not enable the elimination of additives and it generally leads to the progressive deterioration of the material's properties.

Consequently, IFPEN's teams have been working on the development of advanced recycling processes (physical and chemical) that can eliminate additives and impurities in order to achieve a quality equivalent to that of the virgin material.

The large-scale roll-out of these recycling processes requires significant industrial investments. The cost of the raw material derived from advanced recycling is higher than the cost of producing virgin plastic. Thus these new production routes will only develop within a favorable and long-term regulatory framework. In particular, it is necessary to:

- Impose recycled material content requirements in plastic items produced and thus pre-define market sizes that will open up opportunities for the recycled material,
- Set the criteria establishing the end-of-waste status at the prepared feedstock stage (including collection, sorting and shaping operations) so that chemical or petrochemical platforms can process these materials without the need for more stringent classification associated with the presence of waste,
- Introduce a Mass Balance system to encourage plastics to plastics recycling, as proposed by Europe's Fuel Exempt compromise,
- Respect, as far as possible, the notion of "material circularity" at polymer level (PET waste should remain in the PET sector, etc.) to preserve each sector's economy,
- Avoid circularity loops linked to plastic objects placed on the market (for a given polymer) in order to scale up recycling channels and promote economies of scale to limit costs,
- Promote, as far as possible, existing, more environmentally-friendly sectors and take into account technological evolutions over time while giving visibility and perspective to projects using proven technologies.

Background

First introduced in the 1950s, plastic rapidly became established as a material essential to modern lifestyles. The ever-increasing demand for the material stems from its lightness, its ease of implementation, its low production cost and its numerous properties, which can be adjusted depending on the exact formulation.

However, two major challenges have emerged as a result. The first relates to the environmental impacts of plastic, associated with the production or management of the post-consumption waste collected (incineration, landfill), as well as the various forms of pollution related to the dispersal of non-collected waste in the environment. The second concerns the use of resources, with almost all plastic currently consumed having been produced from fossil (oil and gas) hydrocarbons.

Using alternative resources for plastic production, such as bio-based and recycled materials, or CO2, is therefore a key issue, both in terms of our sovereignty and for the environment. The ever-increasing recourse to plastic requires us to take action not only on production methods, but also on the management of usages and end-of-life, to limit the environmental impacts as much as possible, using the three levers inherent to a circular economy: "Reduce, Re-use and Recycle", and maximizing the eco-design of products.

In this context, one of the major challenges is to improve the end-of-life management of plastic objects. First of all, this means collection has to be intensified worldwide in order to reduce the amount of plastic released into the environment. **It is also necessary to continue developing the sorting and recycling sectors, in order to convert as much waste as possible into Recycled Raw Materials (RRMs) that can the be used in place of virgin raw materials.**

A multitude of complex flows to be managed

Plastic is a generic term referring to a multitude of materials made up of polymers primarily, as well as numerous additives that give plastic its specific usage properties (dyes, stabilizers, plasticizers, opacifiers, flame retardants, etc.). These materials are used in every economic sector (packaging, construction, automobile, agriculture, etc.), with very variable usage times ranging from a few days to several decades.

While the composition of the plastics placed on the market is controlled by the manufacturers who produce them, and although the use of additives is increasingly regulated, the exact composition of plastics after their use is not known to recyclers, who must nevertheless adapt to the waste flows they have to process.

Moreover, upstream of recycling, the organization of household and industrial/commercial waste collection and sorting operations is complex and varies between countries. The introduction of EPR (Extended Producer Responsibility) sectors, makes it possible to organize and finance, at least partially, waste management and the development of structures to optimize waste recovery, sector by sector. France was a pioneer in this area with the creation of its *Eco-Emballage* (or Eco-Packaging) initiative (known today as *Citéo*) in 1992 to manage end-of-life packaging.

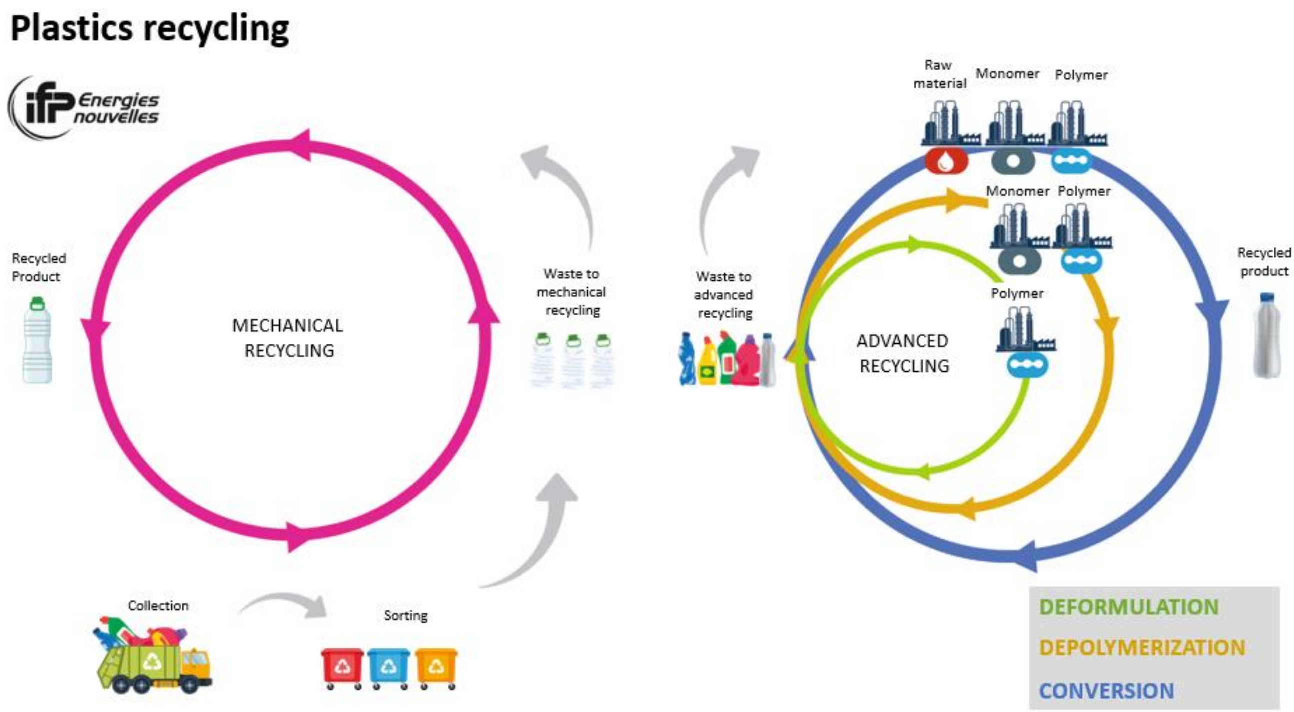
The development of recycling processes therefore needs to be coordinated with the introduction/evolution of waste collection, sorting and preparation processes in order to transform waste into useable feedstocks. Consequently, investment in ambitious recycling projects requires in-depth knowledge of the available resources in order to identify and secure them, and to ensure that they are compatible with the treatment capacities of the recycling process in question.

Today, although waste collection and recycling are becoming better organized in many countries, there is still considerable room for progress when it comes to optimizing the collection and processing of collected flows, but also in terms of **standardizing the sorted flows** with a view to facilitating their subsequent recycling and reduce related costs.

Plastics recycling

Today, most recycled plastic is derived from mechanical recycling, a process that has developed over the last 30 years. The technique has been well perfected and addresses numerous needs. However, there are limitations in terms of its implementation:

- It is restricted to very well sorted waste flows (often homogeneous by type of plastic or the objects they contain), waste that is not always available or accessible,
- It does not enable the elimination of additives (dyes, phthalates, etc.),
- It is not always possible to decontaminate the plastic and return it to food-grade quality,
- It does not always return the material to its original state (closed loop), and sometimes leads to downcycling,
- After a few recycling cycles, the aging of the material leads to the gradual deterioration of the polymers and, consequently, of some plastic's useful properties.



Advanced recycling, complementary to mechanical recycling, consists in chemically or physically treating end-of-life plastic through deformulation, depolymerization and conversion. The different advanced recycling processes make it possible to remove the additives and other impurities present in waste and recover the initial plastic, by employing transformation techniques of varying durations, and thus promoting closed-loop recycling.

In this context, IFPEN is actively involved in the development of advanced industrial recycling processes. The three recycling options specified below are explored in relation to the needs of different sectors (see annex).

All plastics recycling processes have an environmental impact that depends on the nature of the treatment operations and the steps required to convert the material. Short loops, using deformulation, make it possible to obtain recycled polymers directly, while wider loops, using conversion, require a greater number of chemical transformations before returning to the polymer. It is therefore generally considered that the wider the recycling loop, the greater the environmental impacts attributable to the RRMs, even though they are generally much lower than those attributable to equivalent virgin materials produced from fossil hydrocarbons.

Today, plastics recycling is a considerable challenge given the complexity and variety of flows to be treated. All potential options must therefore be explored in order to move towards a truly circular economy for plastics. Where technically possible, priority should be given to mechanical recycling, followed by deformulation, depolymerization and, finally, conversion.

Building a regulatory framework for a rational, effective and durable plastics recycling sector

The investments required to increase plastics recycling management capacities with advanced recycling are considerable, and far greater than any previous investments in mechanical recycling. This often generates an additional cost compared to the production of virgin plastic, which, generally speaking, takes place in production units that have long since been amortized. It is therefore important to establish a framework that enables investments to be justified and secured, in order to reassure and encourage investors. To achieve this, it is particularly important to pursue the implementation of a regulatory framework encouraging the substitution of virgin plastics by their recycled equivalents, in order to stimulate the industrial emergence of true closed-loop circularity around plastics, avoiding, as far as possible, downcycling.

Today, Europe has established a regulatory framework (EU2022/1616) for advanced recycling. It is now necessary to support its development and confirm its status by integrating advanced recycling loops into the waste prevention and management hierarchy.

1. **Promoting the use of RRMs**

An effective way of increasing the use of RRMs and encouraging the demand for recycled plastic compared to virgin plastic is to impose recycled material content requirements in finished products. Such a requirement is proposed for packaging within the draft PPWR (Proposal for Packaging and Packaging Waste Regulation) currently being finalized at European level. The imposed incorporation rates will implicitly define the size of markets. Similar measures are being considered in the textile and automotive industries, and ultimately it would be desirable for all industrial sectors using plastic to be concerned. Given the time required to set up collection, sorting, material preparation and recycling facilities, incorporation rates need to be decided sufficiently in advance, taking into account the highly variable technological maturity of the various sectors.

The growing use of RRMs in consumer products is set to enable the development of recycling sectors, as part of a regional approach to managing our waste and reclaiming our resources.

2. **Defining a coherent end-of-waste status adapted to industrial usages**

Measures need to be put in place to promote end-of-waste status through recycling, at the same time controlling waste treatment and flows. Reflections are underway at the European Commission's Joint Research Center (JRC) to harmonize the end-of-waste status framework for plastics, textiles and tires.

Upstream of the specific recycling operation and irrespective of the sector, it is necessary to carry out substantial feedstock preparation operations, which include collecting, sorting and shaping the feedstock. These are generally mechanical operations conducted by waste-sector players. Feedstock preparation is expensive (between €100 and €500/t, depending on the sector) and is therefore only carried out if there is an existing downstream market. The prepared feedstock meets a set of specifications enabling downstream recycling, either mechanical or chemical. Mechanical recycling is then carried out by processors. Advanced recycling, on the other hand, is generally envisaged on chemical or petrochemical platforms (which are not necessarily approved to process waste).

Adopting a regulatory framework establishing the **end-of-waste status at the prepared feedstock stage and meeting recycling plant specifications** thus appears appropriate and would be applicable to numerous sectors (plastics, tires, textiles, etc.). It would enable:

- The development of a market for raw materials to be recycled upstream of recycling facilities, while limiting the exports of prepared materials, given the value of the feedstocks produced.
- The treatment of prepared feedstocks without additional waste processing authorizations, essential for advanced recycling plants.

3. **Introducing a fair accounting system promoting the most appropriate recycling processes**

When it comes to the advanced recycling of a plastic, it is sometimes difficult, or even impossible, to differentiate between the recycled material and the virgin material, particularly when using conversion processes. It is therefore necessary to introduce robust accounting systems associated with production sites.

The "mass balance" approach, which enables the recycled value of the material produced in a process to be accounted for and attributed according to the yields and nature of the inputs, is therefore an essential device for accounting for, tracing and valuing chemically recycled raw materials. The mass balance system to be set up needs to encourage material recovery, and therefore plastic-to-plastic recycling, and not promote the combustion of the products obtained (notably through the production of transport fuels). The system proposed today in Europe (Fuel Exempt) is a compromise that makes it possible to foster the development of advanced recycling, in a context where incentives to use RRMs remain limited and exclusively concern the packaging sector.

We also advocate that mass balance approaches make it possible to ensure maximum "material circularity" as far as polymers are concerned. Hence, PET waste should preferably remain in the PET sector. Similarly, pyrolysis oils produced from polyolefins should preferably be recycled as polyolefins. So, for example, it is necessary to avoid a situation whereby they are credited for use in recycled PET. In reality, recycling costs are specific to each polymer. It is therefore necessary to ensure that the economy of an environmentally-friendly polymer recycling sector is not undermined by dumping related to lower costs in another sector.

4. What degree of circularity should we aim for?

The growing number of recycling incentives is gradually generating significant pressures to increase and manage resource streams. As a result, the implementation of circularity loops that are highly restrictive not only in terms of materials, but also in terms of sectors and even objects, is now being considered in the various sectors. For example, in the context of PET/polyester recycling, the terms "bottle to bottle", "tray to tray", "fiber to fiber" and even "milk bottle to milk bottle" are employed. However, the smaller the volumes involved in the circularity loop, the higher the costs of setting up collection, sorting and recycling channels on an object-by-object basis.

Consequently, in order to develop sectors that are as economically viable as possible, it is necessary to maximize flows collected locally to promote the deployment of facilities with sufficient capacity on a regional scale, while minimizing the costs of collecting, sorting and preparing feedstock and transporting it to recycling centers. From this point of view, favoring circularity at the polymer level rather than imposing an overly restricted level of circularity, while ensuring the constraints of each sector (food contact, etc.) are taken into account, seems to be the most appropriate approach.

5. Prioritizing the most environmentally-friendly sectors and taking into account technological evolutions

The challenges to be overcome in order to establish widespread plastics recycling and move towards a genuine closed-loop circular economy are considerable, in view of the complexity and variety of the flows to be treated, the structuring of collection and sorting sectors and the investments that need to be made on a world scale. It is therefore necessary to mobilize all available solutions, encouraging the development and roll-out of those that are the most virtuous in terms of their environmental impacts.

For a given plastic waste flow, wherever possible, regulatory measures should therefore encourage the most environmentally-friendly sectors. In this respect, it is thus essential to objectively evaluate **the actual environmental impacts** of all industrial recycling processes in order to better appreciate the real benefits of all of the solutions proposed.

Considerable research and innovation efforts are currently underway around the world dedicated to the theme of plastics recycling. Therefore, viable new technologies will soon emerge to improve existing collection, sorting and recycling systems. Regulatory measures will need to take into account these evolutions while giving visibility and perspective to projects using existing technologies.

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ANNEX

IFPEN has been working on the development of technological solutions to limit the impacts associated with the ever-increasing consumption of plastic for more than ten years:

- By developing innovative, bio-based monomer production solutions, IFPEN aims to enable all of the principal plastics to be produced from renewable, local resources,
- By working on innovative plastics recycling solutions, IFPEN aims to reduce the impact of plastic on the environment by enabling optimized end-of-life waste management, but also to reduce the reliance on fossil resources by the introduction of recycled substitute products of identical or similar quality,
- Developing solutions capable of tackling plastic pollution, in order to characterize/eliminate microplastics in the environment,
- Looking further ahead, IFPEN is also investigating the possibility of converting CO_2 (captured on industrial sites or directly in the atmosphere) into monomers.

Drawing on its expertise developed over the course of the last 80 years, IFPEN has developed advanced recycling solutions intended to complement existing mechanical recycling solutions. The innovative products and processes developed by IFPEN are industrially developed and marketed by its subsidiary AXENS or its industrial partners. These joint research and development projects represent a virtuous model making it possible to take innovations to market so that they can be used by industry.

For example, in the field of deformulation, IFPEN is working with Axens in partnership with industry on the dissolution of polyolefins (specifically sorted PE/PP) and on PVC deformulation (extracting and recovering phthalates in flexible PVC, for example, or separating additives containing Pb and Cd in rigid PVC, etc.).

In the field of depolymerization, working in partnership with Axens and Jeplan, a Japanese start-up, IFPEN has developed REWIND™ PET technology, which has been demonstrated on a semi-industrial scale, to recycle complex (opaque, colored, tray) PET packaging flows, which are difficult to recycle mechanically. The technology uses glycolysis depolymerization to recover the monomer, and then make PET of equivalent quality to the virgin material. This process could also potentially treat polyester-rich textile fibers when upstream feedstock collection, sorting and preparation sectors are operational.

In the field of conversion, Axens proposes the pyrolysis technology developed by Plastic Energy, aimed at recycling mixed polyolefins, preferably plastic films, which are currently poorly recycled by mechanical recycling and most of which are incinerated or sent to landfill. IFPEN, Axens and Repsol have also developed the REWIND™ MIX pyrolysis oil treatment process. The process makes it possible to use large quantities of these oils in refining and petrochemical complexes in order to produce new polymers. The gasification of plastic waste in a mixture with biomass is also possible thanks to the BioTFuel process developed with Axens and a number of other industrial partners. IFPEN and Axens are also developing a tire solvolysis process, making it possible to obtain high-quality recycled solvolysis oil and carbon black. Conversion solutions are appropriate for treating flows with high mixed plastics content, for which very precise selective sorting is difficult. They are therefore complementary to the deformulation process, which enables more targeted polyolefin flows to be treated.

Co-processing is also a potentially interesting option for recycling plastic waste (when other solutions are not accessible), for example in processes such as catalytic cracking (FCC), which produces petrochemical bases (such as propylene) that can then be used for polymerization. Studies are therefore underway with a view to being able to treat plastics or pyrolysis oils in these processes, mixed with conventional hydrocarbon feedstocks.