

**BACK  
GROUND**  
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## ***MECHANICAL RECYCLING***



## ABSTRACT

Mechanical Recycling is currently the dominant recycling technique for post-consumer plastic packaging waste. Sorting and reprocessing technologies are available in most EU Member States with varying levels of recycling quotas. EU waste legislation requires binding recycling targets in the future.

Recycling bio-based plastics increases the fossil carbon reduction potential by keeping the renewable carbon in the material cycle even longer. Drop-in bio-based plastics with the same chemical structure are already mechanically recycled together with their fossil-based counterparts. Innovative bio-based plastics with new chemical structures can be commercially recycled once their amounts in the waste streams become high enough to make this feasible from an economic point of view. For some of these bio-based plastics mechanical recycling already takes place at small scale.

## 1. MECHANICAL RECYCLING TECHNOLOGY LANDSCAPE

### Technology description

Mechanical recycling refers to operations that aim to recover plastics via mechanical processes (grinding, washing, separating, drying, re-granulating and compounding), thus producing recyclates that can be converted into plastics products, substituting virgin plastics. It is also known as material recycling, material recovery or, related to plastics, back-to-plastics recycling. In mechanical recycling, plastic waste (sorted by material type) is milled and washed, passes a flotation separation, and is dried. The plastic flakes are then either used directly to produce new plastic materials or they are processed into granulates beforehand.

Mechanical recycling is used for the recovery of pre-consumer (post-industrial) material as well as for post-consumer plastic waste. It is currently the dominating method of recycling post-consumer plastic waste in Europe. For mechanical recycling, only thermoplastic materials are of interest, i.e. polymeric materials that can be re-melted and re-processed into products via techniques such as injection moulding or extrusion. It is a well-established technology for the material recovery of plastic materials such as polypropylene (PP), polyethylene (PE) or polyethylene terephthalate (PET).

### Sorting

Post-consumer plastic waste is usually a very inhomogeneous and contaminated waste fraction. It comprises a huge range of material types (e.g. multilayer films, blends, and composites) with shape, colour and size varying widely. Therefore, in a first step, the plastic waste passes extensive manual and/or automated mechanical sorting processes

in specialised facilities, designed to separate the different materials. The proper identification of the materials is essential for achieving a maximised purity of recyclates. For this purpose, various technologies such as near infrared (NIR), laser, or x-ray-based techniques are available. NIR-units are widely used and form the state of the art in several European countries for sorting mixed post-consumer packaging. Although sorting technology has increased its accuracy, sorting efficiency never reaches 100% due to separation flaws and laminated or blended products that cannot be separated into their original materials. This often leads to contamination of recycled plastics with other plastics and all kinds of additives. The quality of sorting processes is also dependent on the efficiency of collection schemes, which vary widely even within EU member states.<sup>1</sup>

### Reprocessing

After cleaning and grinding processes, the materials are recovered through remelting and regranulating. The resulting recyclates can be processed with all common technologies for plastics conversion. During melting and reprocessing, high temperatures and shear forces can cause thermal and mechanical degradation of polymers, affecting polymer chain length and distribution. This may influence material properties, such as crystallinity or mechanical strength.<sup>2</sup> If the quality is sufficient after sorting and reprocessing, the recycled materials can be reused in the same or similar products. By recovering plastic materials for reuse, virgin plastic materials are replaced, contributing to a circular economy. However, the resulting quality often only allows the use in lower value applications (so-called down-cycling).

<sup>1</sup> For more information on sorting, please see: "Plastics Recyclers Europe: Guidance on quality sorting of plastic packaging. Establishing highly refined packaging waste streams." 2019.  
<sup>2</sup> Luijsterburg, B.J.: Mechanical recycling of plastic packaging waste. Technische Universiteit Eindhoven. 2015.

**Technology distribution**

In various European countries, plastics collection and recycling systems are in place, focussing mainly on the major, high volume plastics such as HDPE, LDPE, PET, PP and PS. In 2018, 32.5% of post-consumer plastic waste was collected to be recycled in Europe (28 EU member states including Norway and Switzerland)<sup>3</sup>, with mechanical recycling being currently almost the sole form of recycling in Europe. The recycling rates for post-consumer plastic waste vary widely among EU member states, from around 20% in Bulgaria and Finland to up to 45% in Norway.<sup>4</sup> Variation in numbers is due to different calculation methods and differences in definitions. In some Member States, the amount of waste that enters pre-treatment, such as sorting, is already calculated as being recycled, other countries also count waste that is being exported as recycled.

These inconsistencies mean that official recycling rates are neither very meaningful nor comparable. The European Union has started legislative efforts to increase uniform reporting (see below). Data on the amount of waste that is not only collected but also actually recycled is scarce. For the Netherlands, in 2018, 47% of used plastic was collected, of which 33% was actually recycled – a total recycling rate of only 16%.<sup>5</sup> Furthermore, there is a wide range of post-consumer plastics, which are not being recycled because of their low volume or complexity, such as multilayer films, blends, composite items, and items contaminated with food or other residues. It is expected that with further improvements in product design, waste collection and treatment, the volume of recycled plastics will increase.

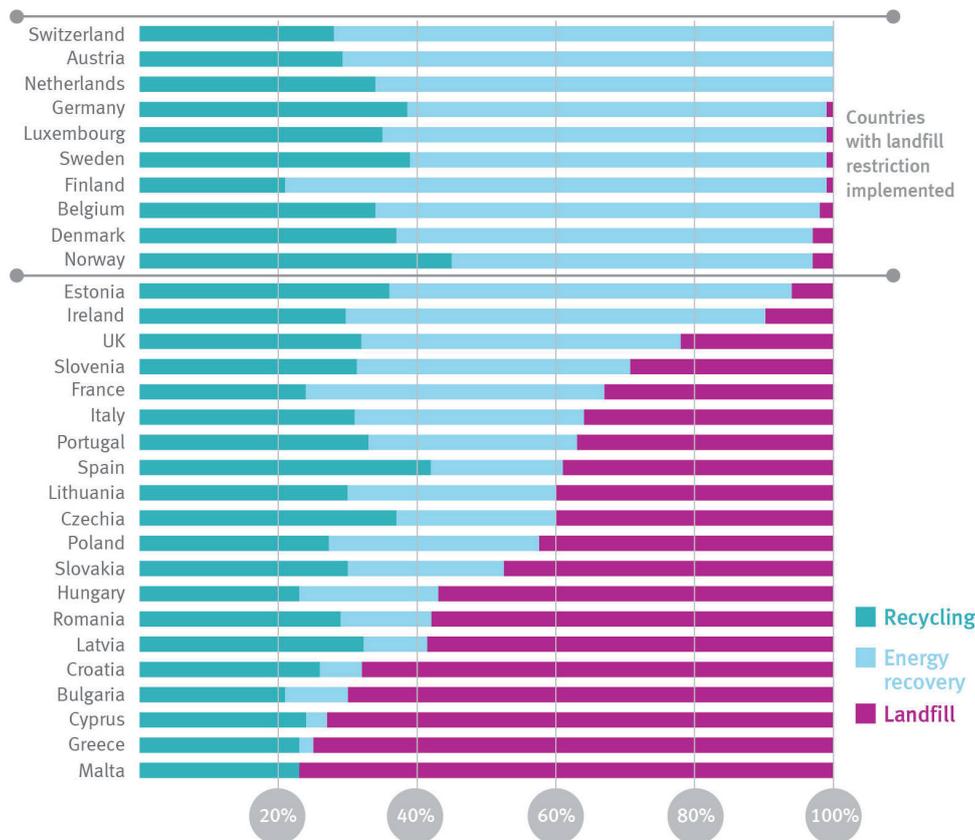


Figure 1: Plastic post consumer waste rates of recycling, energy recovery and landfill per country in 2018. Source: Plastics Europe. Plastics – the Facts 2019.

<sup>3</sup> PlasticsEurope, Plastics – the Facts, 2019.  
<sup>4</sup> Ibid.  
<sup>5</sup> Plastics Europe: Levenscyclus van plastics in Nederland. 2018.

## 2. REGULATORY FRAMEWORK, STANDARDS AND LABELLING

### EU recycling targets

In the European Union, the legal framework for mechanical recycling is laid down in the Waste Framework Directive 2008/98/EC (WFD), the Packaging and Packaging Waste Directive 94/62/EC (PPWD) and the Landfill Directive 1999/31/EC (indirectly).

EU legislation poses new requirements to the plastics and recycling industry, extending the share of recycling over time. In May 2018, a new European waste legislation package was adopted, which sets out new legally binding targets for recycling, within the EU's drive towards a Circular Economy<sup>6</sup>. General recycling targets for municipal waste have been set at 55% by 2025, and 60% by 2030. General targets for plastic packaging waste have been set at 50% by 2025 and 55% by 2030. The legislation, which enshrines the waste hierarchy into European law, also contains a landfill reduction target, and sets minimum requirements for Extended Producer Responsibility (EPR). According to the revised EU legislation, the recycling rate is calculated as the share of recycled material of the total generated amount of plastic waste. Materials are counted as recycled when passing recovery or recycling operations or after preparatory operations for subsequent reprocessing into products, materials or substances. Member States were required to transpose the directive into national law by 5 July 2020.

Quality, price and contamination are the main issues that currently hamper industry demand for recycled plastics. A further key issue is food contact compliance of mechanically recycled plastics, the rules for which are explained in the Commission Regulation (EC) 282/2008.<sup>7</sup> Potential measures to increase demand include a mandatory design for recycling, targets for recycled content or quality standards for recycled plastics. The Single Use Plastics Directive foresees a minimum recycled content for PET beverage bottles by 2025<sup>8</sup>, with other products potentially being added in the future.

In December 2018, the European Commission launched the "Circular Plastics Alliance" with the aim of having 10 million tonnes of recycled plastics used to manufacture new pro-

ducts by 2025.<sup>9</sup> This is supposed to boost awareness and demand and shall be achieved by reliable self-commitments of the industry.

### Standards and Labelling

The standardisation of recycled plastics largely has been driven by the Packaging and Packaging Waste Directive 94/62/EC (PPWD). It requires that Member States ensure that packaging complies with the "Essential Requirements" (laid down in Annexe II of the PPWD), which have been "translated" into standards by CEN. Plastic recycling and recyclates are defined by a number of standards of the EN134xx (Packaging) and the EN 1534x (Plastics) series. These standards define e.g. minimum quality criteria of recycled plastics and criteria for recycling.



Figure 2: Recycling code for "other plastics"

Bio-based equivalents of conventional polymers will use the existing corresponding recycling code (e.g. bio-based LDPE will use code "4"). Innovative bio-based plastics are labelled with the code "07" for "other plastics". However, this type of material identification is becoming much less important for sorting processes due to the increasing use of automated sorting (e.g. NIR-technology).

<sup>6</sup> This waste package (Directive (EU) 2018/851) amended the Waste Framework Directive (2008/98/EC).

<sup>7</sup> Currently, only PET is approved for food contact when using mechanical recycling of post-consumer PET waste. Other materials are not approved.

<sup>8</sup> Directive (EU) 2019/904 requires 25% recycled plastic by 2025 in PET bottles and 30% by 2030 in all types of beverage bottles.

<sup>9</sup> The basis for this aim is Annex III of the European strategy for plastics (COM/2018/028).

### 3. BIO-BASED PLASTICS IN MECHANICAL RECYCLING

Bio-based plastics include a range of materials. Many of them, for example bio-based PET, bio-based PP and bio-based PE (so called drop-ins) are bio-derived equivalents of conventional plastics having the same chemical structure and physical properties. On the other hand, for a number of bio-based plastics no fossil-based equivalent exists. These are often referred to as innovative bio-based plastics and include polymers such as polylactic acid (PLA), polyethylene furanoate (PEF) and polyhydroxyalcanoate (PHA). The origin of the feedstock (renewable or non-renewable resources) plays no role for the recyclability properties of these materials. When different kinds of plastic products are recycled (either conventional plastics or bio-based plastics), the potential incompatibilities between individual polymers have to be considered in all cases. That is why a maximum of uniformity of the processed material stream needs to be achieved via sorting.

By recycling bio-based plastics, the prolonged carbon sequestration in products is advantageous, further improving their environmental performance. The value of the polymerisation process with regard to energy and other resource intake is preserved.

#### **Drop-in bio-based plastics: Compatibility**

Products made of bio-based equivalents of conventional polymers (so-called drop-ins with the same chemical structure) do not differ from fossil-based products when it comes to mechanical recycling. Bio-based PE or bio-based PET, for example, are chemically identical to their fossil-based counterparts and thus behave exactly the same during the process of mechanical recycling. If a separate recycling stream for a certain plastic type exists, a bio-based version of it can be easily recycled alongside its conventional counterpart (e.g. bio-based LDPE in the LDPE stream or bio-based PET in the PET stream). A study conducted by Wageningen University, which simulated the entire recycling process of PE shopping bags and measured the mechanical properties of the resulting recyclates, proved that adding bio-PE to post-consumer sorted film does not lower the quality of the recyclates.<sup>10</sup> The quality of recyclates rather depends on the quality of the previous sorting process.

#### **Drop-in bio-based plastics: Economic feasibility**

The economic viability of the recycling of drop-in bio-based plastics relates to the economic viability of recycling their fossil-based counterparts. The drop-in bio-based plastics are integrated in the established waste streams. Therefore, there is no need to adapt the existing mechanisms and infrastructure.

#### **Innovative bio-based plastics: Compatibility**

Innovative biopolymers with different chemical structures can also be recovered through mechanical recycling. NIR systems can be programmed to identify new polymers or variations of polymers. With the implementation of NIR scanning methods in the sorting of post-consumer plastics, the detection of innovative bio-based plastic types and its forwarding to specified material streams is possible and will lead to a level of purity of recyclates, which is uncritical for the majority of applications.

For example, NIR sorting was utilized to identify PLA in recycling streams and to successfully separate it from the mixed plastics fraction.<sup>11</sup> This was confirmed by a further test, in which PLA packaging was mixed with post-consumer lightweight packaging waste and was successfully separated using common NIR-sorting technologies.<sup>12</sup> Mechanical recycling trials have demonstrated that the presence of PLA in a film waste fraction does not negatively influence the properties of the recycled film.<sup>13</sup>

The intended end-of-life option for bio-based compostable plastic products is organic recycling in industrial composting plants. It is by no means supposed to replace mechanical recycling, but rather presents an alternative recycling option. The value of compostable plastic products does not lie in their material recovery, but rather in the diversion of biowaste to the composting or anaerobic digestion plant.

<sup>10</sup> Karin Molenveld et al.: Influence of bio-PE shopping bags on the quality of recycled film from SITA. Wageningen UR Food & Biobased Research, December 2014.

<sup>11</sup> NatureWorks LLC. Using Near-Infrared Sorting to Recycle PLA Bottles. [http://www.natureworkslc.com/~media/The\\_Ingeo\\_Journey/EndofLife\\_Options/mech\\_recycling/20090708\\_NatureWorks\\_UsingNIRSortingtoRecyclePLABottles\\_pdf.pdf](http://www.natureworkslc.com/~media/The_Ingeo_Journey/EndofLife_Options/mech_recycling/20090708_NatureWorks_UsingNIRSortingtoRecyclePLABottles_pdf.pdf)

<sup>12</sup> PLA in the waste stream, 2017, Result Summary, project supported German Ministry of Food and Agriculture (BMEL), <https://www.umsicht.fraunhofer.de/content/dam/umsicht/en/documents/press-releases/2017/pla-in-the-waste-stream.pdf>

<sup>13</sup> Bio-based and biodegradable plastics - Facts and Figures, Wageningen Food & Biobased, Report number 1722, 2017, pp 41 and pp 46.

**Innovative bio-based plastics: Economic feasibility**

Mechanical recycling of innovative bio-based plastics is not so much a question of technical practicality, but of economic feasibility. Mechanical recycling of the bio-based polymer PLA is already applied commercially.<sup>14</sup> Post-consumer recycling of bio-based plastics, for which no separate stream yet exists, will be feasible as soon as the commercial volumes and sales increase sufficiently to cover the investments required. New separate streams will be introduced in the

short to medium term. Preconditions for establishing the successful mechanical recycling of innovative bio-based plastics are the growing amount of bio-based plastics in the recycling stream, to justify additional investments, and an existing market for the resulting secondary raw materials. This is in principle valid for any material on the market and this will allow material cycles to be closed.

<sup>14</sup> Interview EUBP, Steve Dejonghe, Looplife, <https://www.european-bioplastics.org/r-pla-is-an-attractive-option-due-to-its-recycled-and-bio-based-nature/>. November 2017.

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