Factsheet 11 | How can high-quality recycling be ensured?

This factsheet outlines the key elements of plastic recycling systems, including the technologies required to recycle different types of plastic and packaging. It shows how packaging waste can be recycled in an EPR system.

An important aim behind the introduction of an EPR system is to ensure that the resources contained in discarded packaging are effectively re-used. Moving towards a circular economy means ensuring that packaging waste is recycled to the highest possible levels of quality, among other requirements. In many countries, achieving this objective means gradually building up recycling infrastructure, step by step. An EPR system can be very helpful in providing a sound financial and organisational platform for this development.

One of the requirements the PRO has to meet is to ensure all obligations arising from legislation and regulations are fulfilled. For this to happen, it needs to enter into appropriate contractual agreements with waste management companies and recyclers.

Recycling packaging waste

Definition of recycling

In this EPR toolbox, **recycling is defined as closing material loops**, i.e. processing materials in order to produce recyclates, regenerates, blends or alloys that replace virgin raw materials in standard applications. This benchmark is represented by the dark green line in Figure 1.

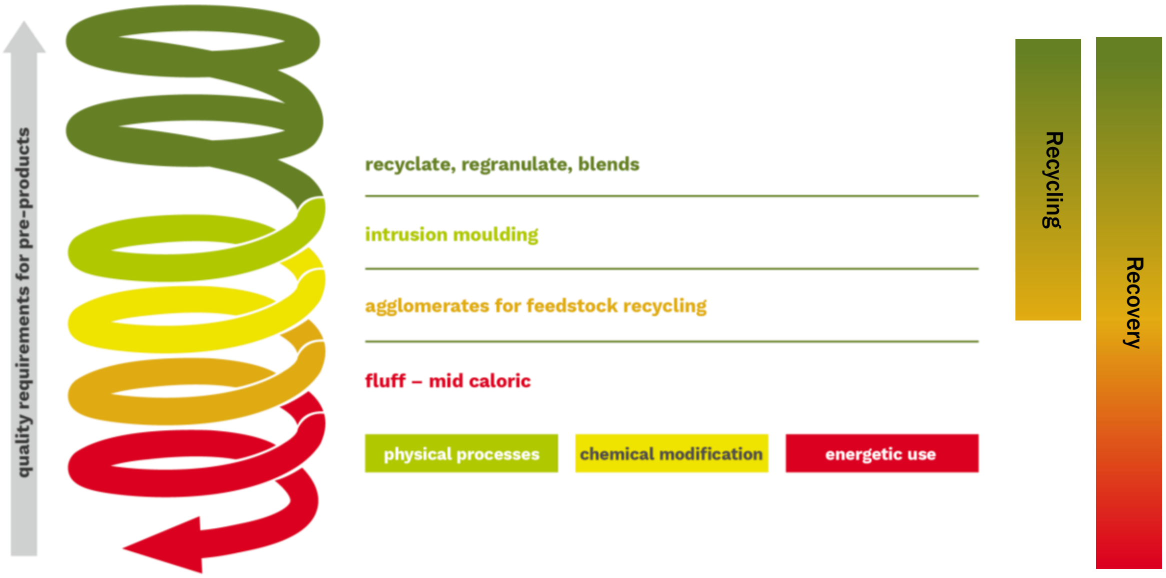

Figure 1: Defining the term 'recycling' (Source: Institute cyclos-HTP 2019, own representation)

Recyclate, regranulate, blends: The dark green top section of the spiral in Figure 1 shows the basic understanding of **high-quality closed-loop recycling**. In this case, virgin material can be substituted completely (e.g. bottle-2-bottle recycling). The second dark green spiral indicates a lower level of quality (for example for the production of polyolefin-based regranulates made from yoghurt pots). These re-granulates and blends can also replace virgin material for various non-food packaging applications such as in flower pots or pipes. Only recycled material (recyclates, regranulates, blends) within the top two spirals can replace virgin raw material and therefore, only packaging and products that can be recycled at this level are classified as recyclable.

Intrusion moulded products: This process is also considered as part of mechanical recycling. In this category, plastic material is melted down into a paste and transformed into molten parts using presses. End-products could be park benches or fences. These processes do not require high-quality recycling.

Agglomerates for feedstock recycling: The threshold used to define 'recycling' in this context is that set out in European Union's Waste Framework Directive and in Section 3 of the German Circular Economy Act (*Kreislaufwirtschaftsgesetz)*. It includes products used for feedstock recycling (in gasification processes).

Fluff or mid-caloric materials: This category covers energy recovery. The recycled product is used in co-incineration in cement plants, substituting other fuels.

In **preparation for the recycling process**, packaging waste must be thoroughly sorted into its various fractions. The main stages of the sorting procedure are: 1) Screening and wind sifting (film sorting for LDPE). 2) Magnetic separation (ferrous metals) and eddy current separation (non-ferromagnetic metals). 3) Sensor-based sorting to sort form-stable plastics by plastic polymer (HDPE, PP, PET and PS).

Main recycling paths

Sorted packaging can be marketed and recycled depending on their product specifications (e.g. maximum contamination) as agreed upon with the recycler. Figure 2 gives an overview of the main recycling paths for packaging once it has been sorted. It shows the basic procedures that have to be carried out to produce the various different types of recyclates.

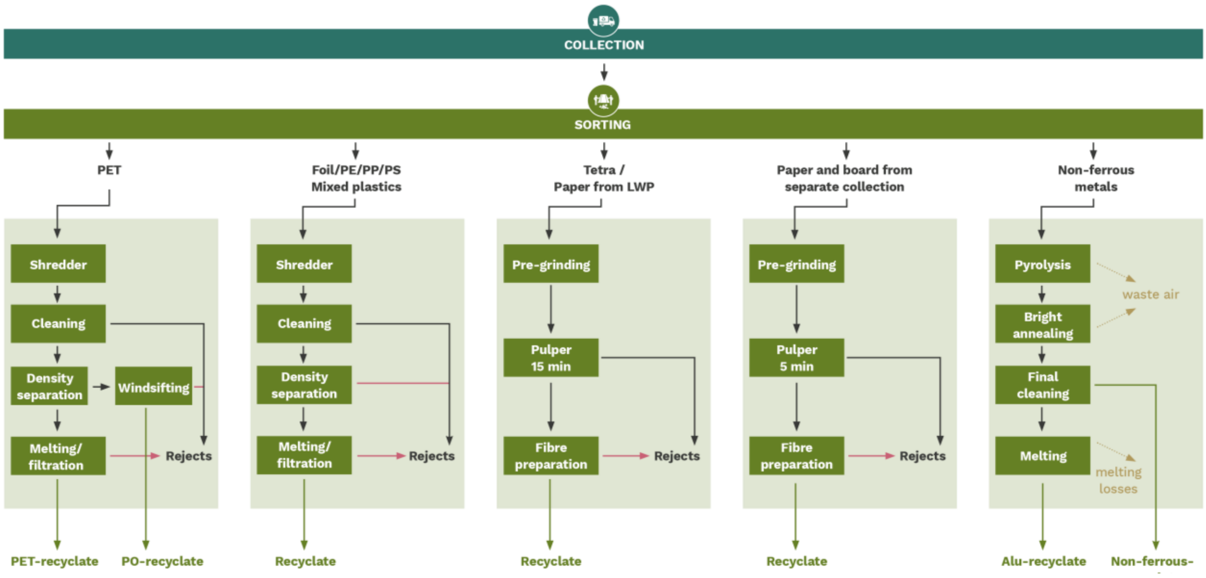

Figure 2: Recycling paths for packaging (Source: Institute cyclos-HTP 2019, own representation)

Fibre-based packaging (TetraPak/paper made from LWP) is processed in paper mills. Paper and board is collected separately to other waste and is then pulped in an industry-standard process lasting 5 minutes. Liquid packaging board is sent on to special waste paper processing lines designed for longer pulping times (approx. 15 minutes). Aluminium and plastics are rejects in this process, which produces pulp for making paper.

The aluminium fraction (non-ferrous fraction) is then processed further using pyrolysis. In this process, the material is thermally treated under anoxic conditions in order to detach gaseous organic elements, such as plastic coatings, lacquers, residual contents, etc. It can then go on to be re-melted, a process in which oxidized aluminium is slagged. This process produces aluminium recyclates, which are used to refine steel or for casting in the automotive industry.

Thermoplastics (such as PET, PE, PP, PS) are plastics that can be easily re-formed within certain temperature ranges. (For some specific polymer types, the curing process is reversible and if this is the case, they are considered thermoplastics, in contrast to thermosetting polymers.) Reversible means that the reforming process can be repeated, which is important for recycling processes. However, there are limits as to the number of times these plastics can be re-formed. Each heating process shortens the polymer chains in the plastics (so-called ‘aging of plastics’). Once a plastic reaches a certain ‘age’, it can no longer be recycled. This process produces recyclates for injection moulding and thermoforming.

Why is it so important for consumers to sort their waste?

Ensuring that waste is separated at consumer level is crucial for high-quality recycling. Packaging materials must be collected separately from residual and organic waste. The better the collected fractions are separated by the time they leave the household, the easier and cheaper it will be to sort them in professional facilities. If consumers comply with instructions to segregate waste, it will be easier to market that waste as an economic resource and an input material for recyclers.
> See Factsheet 06 and 09

Recycling of plastic packaging

Table 1 shows the major thermoplastics from the packaging sector.

Table 1: Thermoforms compared (properties, converter demand, applications) (Source: cyclos 2019)

Type of plastic	Polyethylene Terephthalate (PET)	Polyethylene (PE)	Polypropylene (PP)	Polystyrene (PS)
Recycling code	01 PET	02 PE-HD 04 PE-LD	05 PP	06 PS
Density	~ 1.3 g/cm³	0.91 – 0.93 g/cm³ PE-LD 0.94 – 0.97 g/cm³ PE-HD	0.9 – 0.91 g/cm³	1.05 – 1.06 g/cm³
Melting point	~ 260 °C	105 – 135 °C	160 – 170 °C	240 – 270 °C
Characteristics	**Advantages:** High service temperature Good weathering resistance (UV light)	**Advantages:** Low density Low moisture absorption High chemical resistance High elasticity Easy to dye	**Advantages:** Low density No moisture absorption High chemical resistance Good fatigue strength Some types approved for food contact	**Advantages:** Low density No moisture absorption High transparency High hardness rating Surface gloss
	Disadvantages: Degrades in hot water (> 80°C) Low resistance to strong acids, alkalis, oxidizing agents, alcohols	**Disadvantages:** Not suitable for temperatures > 80°C High stiffness in combination with poor tensile strength	**Disadvantages:** Brittle at low temperatures (if unmodified) Low UV-resistance (unmodified) Low scratch resistance	**Disadvantages:** Brittle Yellows if used outdoors Low chemical resistance
Value	Average material value	Low material value	Low material value	Low material value
Converter demand by polymer types[1] EU28+CH, NO	7.4%	29.8%	19.3%	6.6%

[1] European plastic converter demand by polymer types in 2017, Plastics – The facts 2018, Plastics Europe

Type of plastic	Polyethylene Terephthalate (PET)	Polyethylene (PE)	Polypropylene (PP)	Polystyrene (PS)
Suitable for	Drinks bottles, trays, films	Rubbish bags, carrier bags, waste bins, jars, bottles	Car battery casings, household products (folding boxes with hinges, bowls, storage containers), flower pots	Cups, CD covers, Can be used as foam for Insulation panels in the construction industry. Shock-absorbent packaging, egg cartons, meat dishes (extruded films)
Processing methods	Injection moulding, blow moulding, film blowing, extrusion	Injection moulding, blow moulding, extrusion	Injection moulding	Injection moulding, extrusion, film extrusion

Recycling PE, PP, PS or foils after sorting

In modern (state-of-the-art) sorting plants, the mixed lightweight packaging material stream is optically sorted using NIR-technology according to the different plastic types in the stream (PE, PP, PS, film).

The diagram below shows how pre-sorted packaging goes on to be further processed, taking polyethylene (PE) as an example. The process known as **swim-sink separation** is the key step for recycling PE packaging.

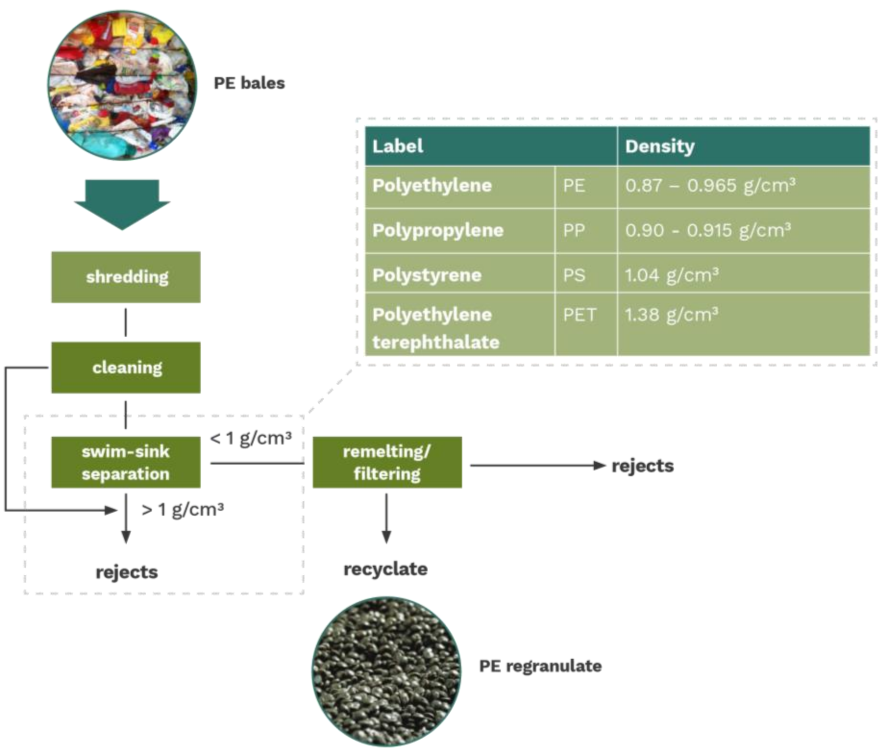

Figure 3: The recycling path for PE after sorting (Photos: © cyclos)

First of all, the input material (in this case the PE packaging) needs to be **shredded into small pieces.** This is followed by a **wet cleaning** phase before **swim-sink separation,** which is the key to producing high-quality recyclates. The material is separated based on the specific weight of the plastics in relation to the water in which it is separated (separation threshold 1g/cm³). **Polyolefins (PE, PP) float (or swim) in water** (the separation medium), whereas plastics with densities > 1g/cm³ (PET, PS, PVC) sink, which helps to separate out any impurities. Polyolefins (PE, PP) are separated in swim-sink tanks. They are discharged via paddle rollers. Afterwards, PE regranulates are produced in a **re-melting** process. The material (regrind) is injected from a hopper and forced forward into a heated barrel via a rotating screw (the melting temperature is about 230 °C with PO). Finally, the molten material is filtered in order to remove any remaining impurities.

PE regranulates can be suitable for processing into **high-quality products.** A few examples are shown in Figure 4 below:

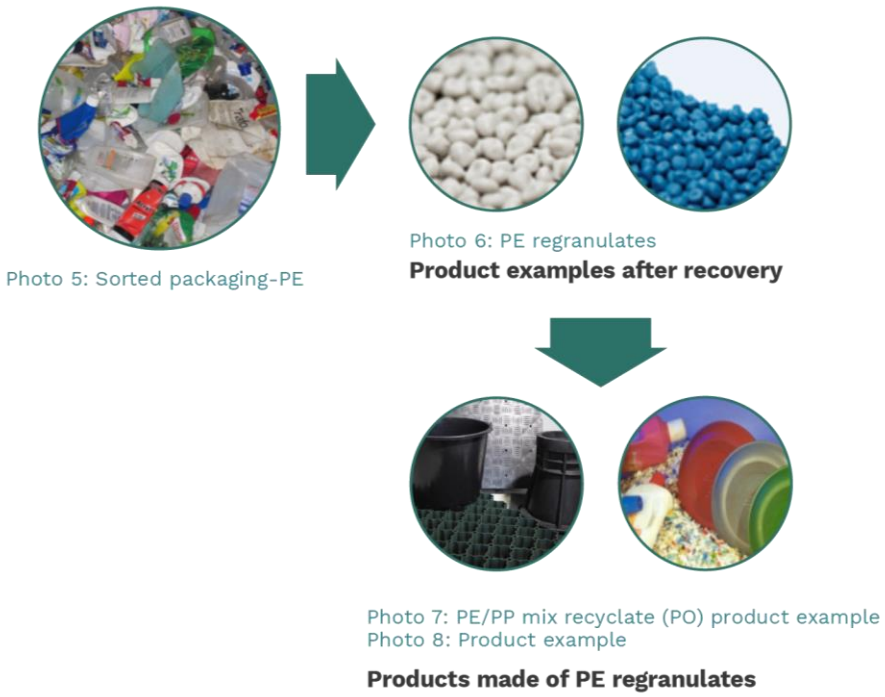

Figure 4: Recycling PE packaging (Photo 6: © Vogt-Plastic GmbH, Photos 5, 7, 8: © cyclos)

The general recycling process is shown here using the example of polyolefins (PE, PP).

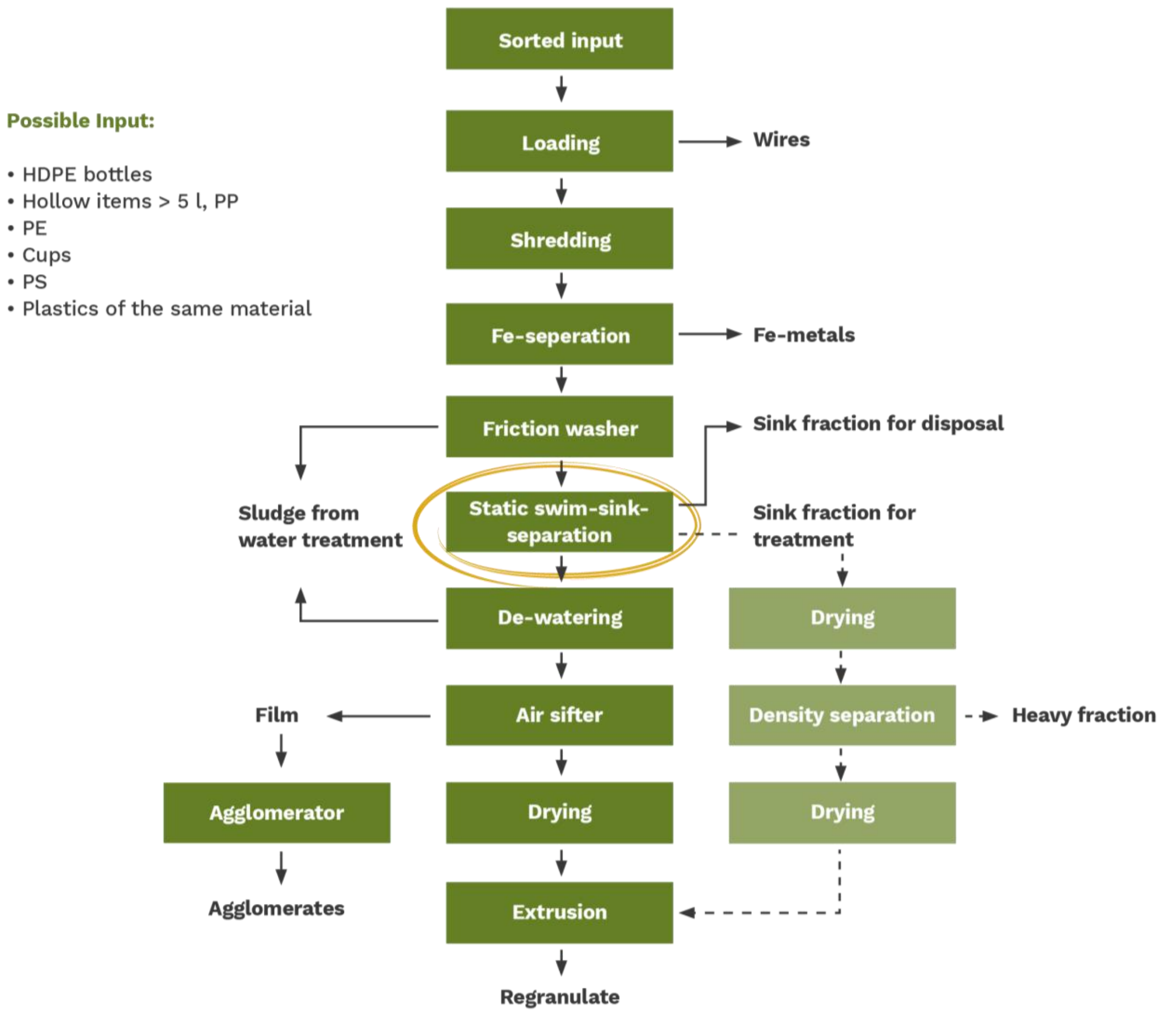

Figure 5: A recycling path for PE, PP, PS or foils after sorting (Source: Institute cyclos-HTP, own representation)

As previously mentioned, swim-sink separation is the key step within the recycling path.

Recycling PET bottles

To produce high-quality recyclates from PET bottles, the first step is to remove **banderols, lids and other items made of materials other than PET.** Since lids are made of PO, an additional separation step is required in order to retrieve the PO fraction.

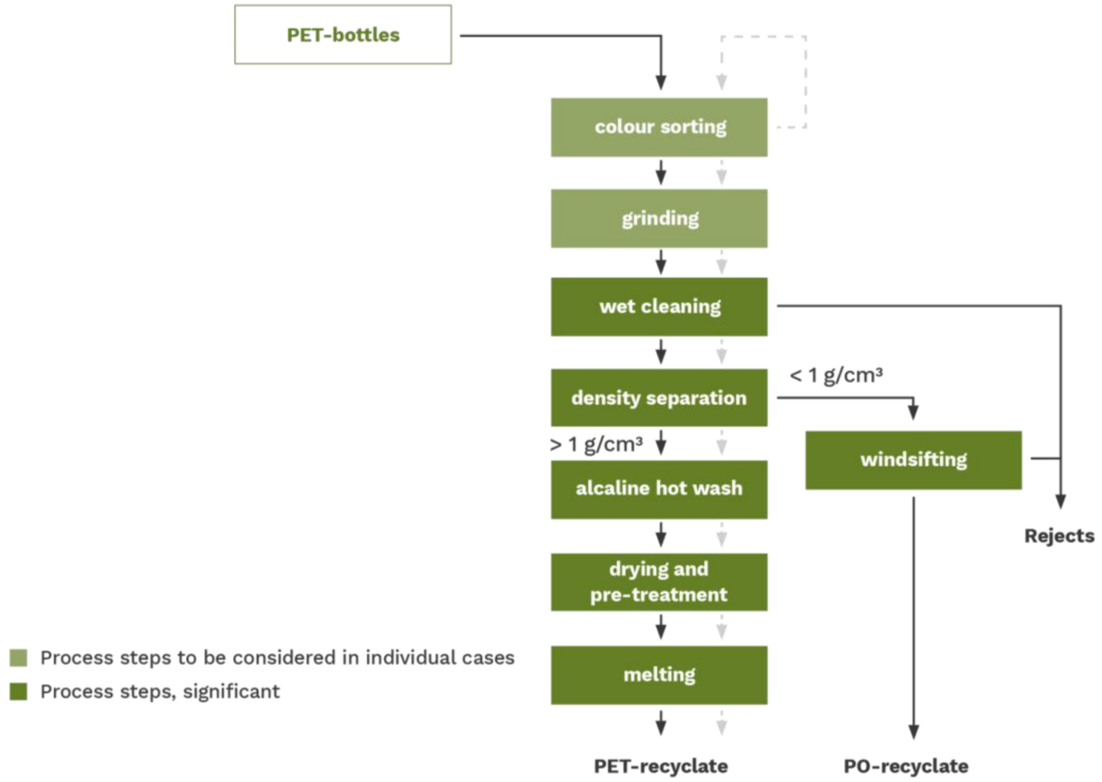

Figure 6: Recycling path for PET-bottles (Source: Institut cyclos-HTP 2019[2], own representation)

Figure 6 illustrates the **state-of-the-art technical process**, required to produce high-quality plastic products. Processing is done using a **two-step washing process** made up of an alkaline hot washing process (at 80 °C with caustic soda) and swim-sink separation. **Extrusion** takes place at re-melting temperatures up to 285 °C and with melt filtration.

PET flakes can also be further purified for use in **bottle-to-bottle recycling** processes. There are two common processes for this, SSP and URCC:

SSP-process (Starlinger):

- Basic process: Melting – melt filtering – granulation – crystallisation – solid state process (SSP). Produces PET granules.

URRC-process, food-grade PET flakes

- Basic process: Surface treatment of the flakes with caustic soda – material is dried and fed into a large rotary kiln for intense surface cleaning. No re-melting takes place.[3]

Differences between low-tech, low quality recycling and high-quality packaging recycling

In many countries around the world, packaging and other plastic items are recycled using a very **simple technical process.**

Photo 1 shows a very simple plastic shredder, used in Jordan for shredding various polyolefin (PE, PP) items. The shredded particles drop straight into a basin of water. The lighter fractions float to the top and are removed for recycling.

[2] Institute cyclos-HTP, 2019: "Verification and examination of recyclability"
[3] Source: https:// www.veolia.de/urrc-process

The system in the photograph does not comply with environmental standards. Wastewater treatment and other environmental standards must be observed in order to prevent adverse environmental effects on waterways, air and soil, and to stop residual plastic leaking into the environment. Ensuring compliance with occupational health and safety standards is equally important.

Photo 1: A plastic recycler in Jordan (© cyclos 2019)

An EPR system should be used to transition from a low-quality recycling system using simple equipment to a high-quality recycling system built on modern technology. Before improved recycling technology can be bought, installed and used, certain conditions need to be in place, and an EPR system can help to create these conditions:

- Certain quantities of secondary raw materials must be available on a regular basis for each fraction and delivered to the recycling plant. Fluctuations in volumes increase the risk to investors and to the continued operation of recycling plants. As EPR systems are used to collect packaging waste over the long term, rather than for short-term pilot projects, they can play a major role in meeting this requirement.

- The quality of the sorted packaging must consistently meet a set high standard, because the technology is designed to process certain grades of packaging. The system operator (PRO) can help to ensure consistent quality by making contractual agreements with the sorting company that delivers the sorted packaging into the recycling system.

- Recycling is not always economically secure and viable. Depending on the fraction and market situation, additional payments may be required to make the system economic. These additional payments can be covered by EPR fees.

- Sales markets need to be created for the quantities being recycled. The higher the quality of the recyclates, the more options there are to use them. Consequently, the more options there are for recyclates use, the easier it is to create markets. > See Factsheet 13

Key readings and other sources

[PREVENT Waste Alliance (2021).](#)

[Video series:](#)

[EPR Explained! (11) High-quality recycling](#)

Institute cyclos-HTP (2019). Verification and examination of recyclability. Available at http://cyclos-htp.de/fileadmin/user_upload/2019_Katalog/Verification_and_examination_of_recyclability_-_Revision_4.0.pdf

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