May 13th 2025

Pack for the Future

Recyclability a cornerstone of circularity

Wageningen Food & Biobased Research

Kennisinstituut Duurzaam Verpakken
onderdeel van verpact

Fostplus

Recyclability

- The ability to be recycled (of plastic packages)

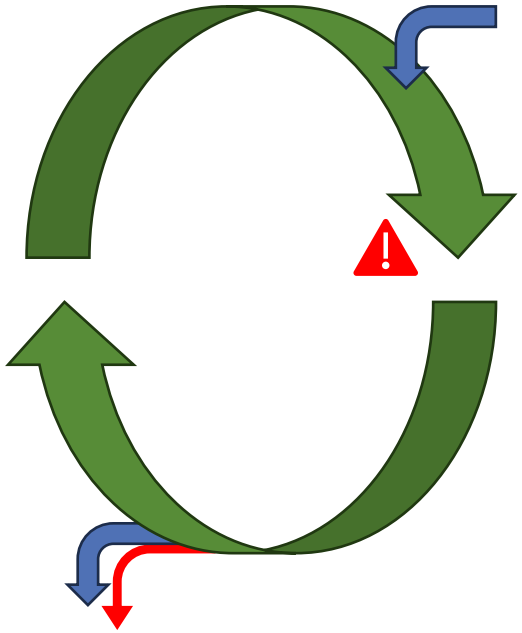
- Its practical meaning depends on:
  - The objectives of the recycling system - the goal
  - The infrastructure that is in-place - the means

- Consequently, its practical meaning
  - has varied between countries, but is converging within the EU
  - and will change in time due to
    - New infrastructure
    - New political objectives
    - New scientifical insights

Scientific perspective on plastic packaging recycling

- The quality of plastic after use
  - Level of degradation during use
  - The accumulation of contaminants
    - Non-targeted plastics
    - Other materials
    - Molecules / volatiles

- The quality of plastic after recycling
  - Restoration of polymers if possible
  - The removal efficiency of contaminants
    - Non-targeted plastics
    - Other materials
    - Molecules / volatiles
      - Neo-formed NIAS (chemistry happens)

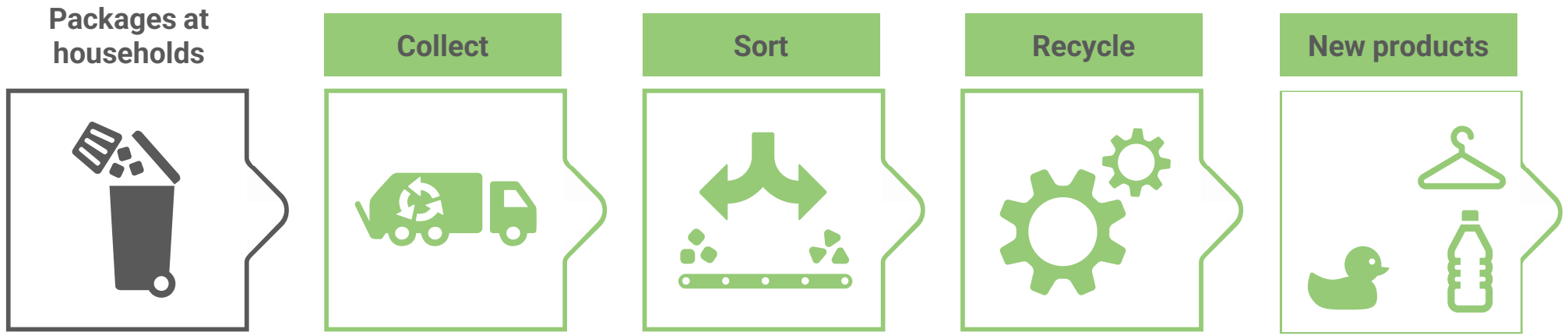


High quality recycled plastic requires

- Good feedstock (targeted packages only)
- Managing / restoring degradation
- Sufficient removal of contaminants
- Effort / energy

Early principles of recyclability (PRE 2021)

1. Plastic packages are collected for recycling
2. Plastic packages are targeted for sorting into sorted products which are traded to recycling companies
3. Sorted products are recycled
4. The recycled plastic is used to make new products



Changes since 2021 - 1

- Experience of recyclers showed that details do matter in recyclability
  - Some polyamides in PE or PP are worse than others, etc.
  - Some potential contaminants in the presence of compatibilisers are less bad
  - Hence a case-by-case assessment is required with experimental testing -> Recyclass method

- 2018: PPWD 852/2018 with raised recycling rate targets
  - Plastic packages: 50% in 2025 and 55% in 2030 + National objectives
  - Urges Fost-Plus and Verpact started to eco-modulate their fees
    - Fost-Plus uses its explanation to the Green point fees
    - Verpact uses the KIDV recycling checks

Changes since 2021 - 2

- 2023: New scientific insights in chemistry during recycling in 2023
  - Mutagens are formed during thermal conversion of mostly printed plastic packages
    - Nitrocellulose decomposes to nitrosamines
    - Azo-colorants decompose to primary aromatic amines …
  - It is challenging to blow a new PE bottle from a recycled PE that contains a mixture of PE grades

- 2024: Recyclers started to market rPE and rPP for personal care packages

- 2025: PPWR
  - Demands that all packages should be recyclable from 2030
    - 2028: CEN will publish standards for recyclability, which will be formally adopted
    - 2035: Packages need to be recycled-at-scale
  - Demanding recycled content in all packages from 2030 on

The principles of a future CEN definition of recyclability

- The level of targeted material in the main component should be maximised
  - A, B and C grades
- Non-targeted components should be removable during sorting & recycling
- Non-separatable substances / components should be minimised and proven to be compatible
- Substances of concern should be phased-out

Recycled content

Minimum recycled content targets

Any plastic part of packaging will have to contain a minimum percentage of recycled content.

Exemptions

- for compostable plastic packaging
- packaging whose plastic component represents less than 5% of the packaging's total weight
- for infant food, medicinal products and medical devices.

➔ The targets are set per packaging type and format and will be calculated as an **average per manufacturing plant** and year.

	2030	2040
 SUP bottles	30%	65%
 Contact Sensitive Plastic (PET as major component)	30%	50%
 Contact Sensitive Plastic (PET not as major component)	10%	25%
 All other Plastic Packaging	35%	65%

Mirror clause | Safeguard clause

PPWR: The most straight-forward approach…

Type of plastic packaging	Suggested origin of recycled content
PET beverage bottles	Current mechanical recycling of PET
PET trays, clear	Current mechanical recycling Depolymerisation -> erecting an industry
HDPE, PP, PS beverage bottles	30%?
HDPE, LDPE, PP food pack	10%?
HDPE, LDPE, PP non-food	Urgently better-quality recycled plastics needed

PET bottle recycling as an iconic example

PET a unique case

- **Degradation can be restored**
- PET's polymer chain length reduces with every washing step & thermal conversion process
- But it can easily be restored with solid state processing (SSP)

- **Standardised packaging design**
- High volumes
- Packages from different brands are sufficiently similar

- **Most PET bottles are well-recyclable**
- PET bottle recycling started in the 90's
- Early lessons on how designs affected the quality of the recycled PET were quickly learned
  - PS base cap disappeared
  - PP labels were made removable
  - HDPE /PP caps were easily removed
- Disturbing innovations were either kept out or stopped after recycler's protest
  - Oxygen absorbers
  - Silicon rubber rings and spouts

rPET from PET bottles

- > 200 combinations of PET bottle feedstocks and recycling processes have received positive opinions of EFSA in the past
- EFSA published the re-evaluation guidelines (August 30th ‘24)
- 56 combinations of PET bottle feedstock and recycling processes have received a formal approval of the EC

  First time ever...

- It is running business at a 2.6 mln tonne feedstock capacity (2022)

Contamination pathways for PET bottles

1. Degradation of the base resin: acetaldehyde, 2-methyl-1,3-dioxolane, ethylene glycol, oligomers
2. ~~Degradation of IAS~~: (no IAS present in PET)
3. Product residues and degraded residues: Limonene, linalool
4. ~~Consumer abuse~~: (evidence is lacking, incidence rate must be very low ~0.03-0.04%)
5. Migration from labels: Plasticisers
6. Cross-contamination with other packages & objects
7. Cross-contamination via the atmosphere
8. Thermal conversions: benzene, styrene

Still some unresolved chemistry is happening
Acetone, Acrolein, BPA, Butanone…

DOI: 10.1002/pts.2528; 10.3390/recycling8010024

Removal of NIAS from rPET

1. Evaporation during life-time: acetaldehyde
2. Migration during use: acetaldehyde
3. Removal during washing: ethylene glycol
4. Vacuum extrusion
5. Dedicated decontamination

SSP: acetaldehyde, benzene, styrene, nonanal, 2-methyl-1,3-dioxolane, PET-dimer...

PET bottle recycling processes

- D4R & separate collection guarantee feedstock quality
- Prints are on easily removable labels and caps
- SSP guarantees quality rPET
  - Restores the polymer chains
  - Decontaminates effectively
- Issues with NIAS of unresolved origins
  - Low priority for the public health
  - Potential brand-risk
  - Incidental NIAS with low occurrence rates

Sorted HDPE DKR 329

- Relatively homogeneous
- Mostly bottles
- Milk bottles dominate
- Caps have different colours
- Prints on labels that are removable

Conventional mechanical recycling of HDPE

- Straight-forward mechanical recycling of HPDE
  - Dark green / grey, Strong odour
  - Non-contact sensitive
  - Used for cable lining, large covers, furniture…
- After additional flake-sorting to remove non-targeted polymers
  - Light grey, odour
  - Non-contact sensitive
  - Used for making bottles

Top quality mechanical recycled HDPE

- A few HDPE recyclers produce “natural” and white rHDPE made from LWP for the contact sensitive personal care industry
- After an enormous technical effort to remove all contaminants
- Renders a top quality (colour, odour, impact) for a premium price
- A minor risk remains on high molecular weight contaminants

- These recyclers do currently not aim for an EFSA opinion and approval
- *The feedstock is currently not, yet, sorted to previous food-use only*

PP DKR 324

- Highly heterogeneous
- No dominant package
- Mostly trays, cups, tubs with lids or top-films
- Many are pigmented
- Most packages are printed / have IML

Flexibles DKR 310

- Heterogeneous
- PE /PP based ~ 80% / 20%
- About 20% multilayers
- >60% printed
- >30% pigmented
- Many IAS in flexibles
- High levels of residues

Current uses of mechanical recycled PP and flexibles

- **Conventionally recycled PP**
- Grey, odour
- Likely mutagenic
- Used in paint buckets, automotive applications

- **Conventionally recycled Flexibles**
- Grey, strong odour
- Likely mutagenic
- Used in plastic lumber

- **Top-quality rPP**
- Almost white / natural
- Hardly any odour
- Used in personal care packaging

- **Recycled after strict PE sorting**
- Grey, some odour
- Likely mutagenic
- Used in garbage bags

Prospects for food safe recycled PP and flexibles

- Top-qualities of rPP natural and white are produced from DKR 324, but it is slightly off due to prints. Used for personal care products.
- Residues of printing inks, azo-colourants, PUR-tie-layers cannot be excluded in the recycled PP and Film -> sources of mutagens

- Food safe mechanical recycling can only become credible if

  Printing inks, colourants, tie-layers… can be removed 100%

  Packages of previous food-use can be sorted exclusively

  Decontamination technologies (dissolution?) are developed

Will EFSA positively assess food-grade PE / PP recycling?

- There are no guidelines of EFSA for PE and PP, but:
  We can use the PET bottle guideline and previously rejected rHDPE and rPP cases
- Maximum level of contaminants in PE / PP ~3000 ppm
- We cannot identify all these contaminants and prove they are non-GMR
  So for EFSA they are all genotoxic unless we can prove otherwise
- To reach 0.0481 µg/kg after decontamination a removal efficiency more than 99.999999% is required for all surrogates in a challenge test: *is extremely unlikely / impossible*
- To stand a chance: minimise cross-contamination, identify all contaminants, urgently develop new decontamination technologies, use recycled PE/PP in short shelf life & low exposure applications

Challenges for food-safe recycled polyolefins

- PPWR: from 2030 on 10% RC in all packages, else: *out-of-business*
- To enable this technically, it is essential that:
  - Sorting on previous use (food / non-food)
  - All prints, glues, labels, etc. are removed 100%
  - Detrimental substances are absent in tie-layers, barriers…
  - A new effective decontamination technology is developed (dissolution?)

} recyclability

- To increase the chance of getting a positive EFSA opinion:
  - Mono-collected packages
- To make this an attractive business-case for sorters and recyclers and to facilitate re-compounders:
  - Standardise the packages

Towards more well-recyclable packages

- Eco-modulation
- Recycling guidelines, Recycle checks, Recyclass…
- Ok-list for SME’s

- **Today’s Pack for the future fair**

Fostplus
Philippe Gendebien (Philippe.Gendebien@fostplus.be)

Wageningen Food & Biobased Research
Ulphard Thoden van Velzen (ulphard.thodenvanvelzen@wur.nl)
Bornse Weilanden 9
6708 WG Wageningen

Fost Plus
Olympiadenlaan 2
1140 Brussel

T +32 2 775 03 50
fostplus@fostplus.be

Volg ons