MAUSER
Packaging Solutions

REDEFINING SUSTAINABILITY

PCR TREATMENT OR CHEMICAL RECYCLING?

September 29, 2023

Sustainable packaging – basics do not change

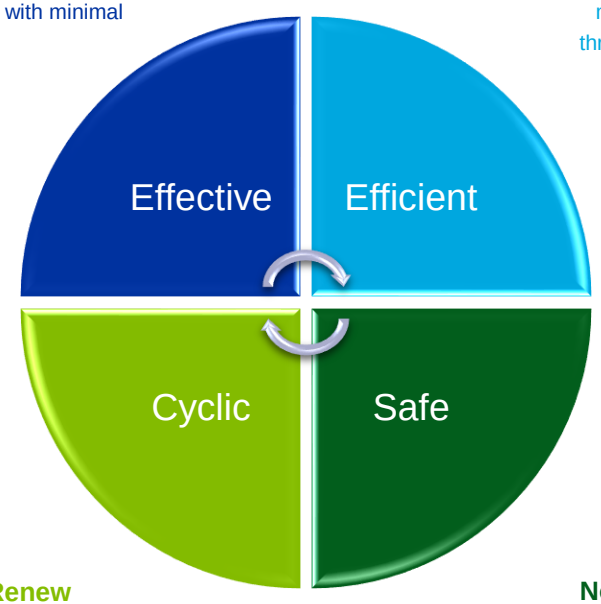
Core Principles

Fit for purpose

The packaging system achieves its functional requirements with minimal environmental and social impact.

Less is more

Packaging designed to use materials and energy efficiently throughout the product life cycle.



Reuse, Recycle, Renew

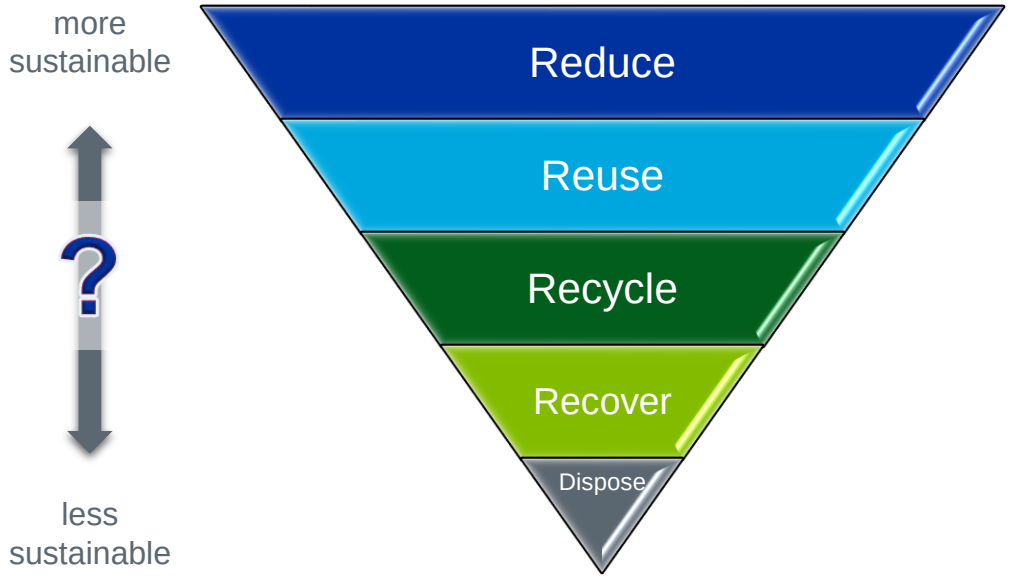
Packaging is designed to reduce reliance on non-renewable resources and to recover them for reuse or recycling.

Non-polluting & no-toxic

Only non-polluting and non-toxic materials are used within packaging and its production process to not pose any risk to humans or the ecosystem.

Source: „Principles, strategies & KPIs for packaging sustainability - Framework 1.0“, Sustainable Packaging Alliance, July 2010

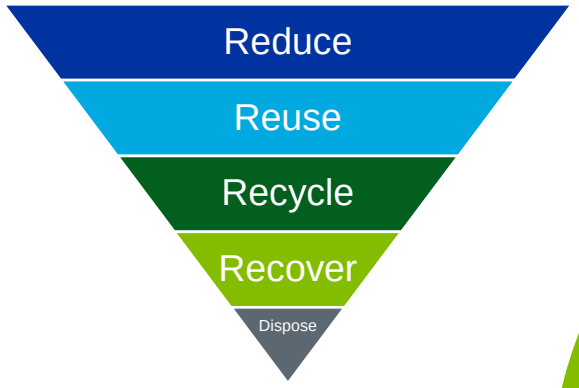
Hierarchy of resource efficiency

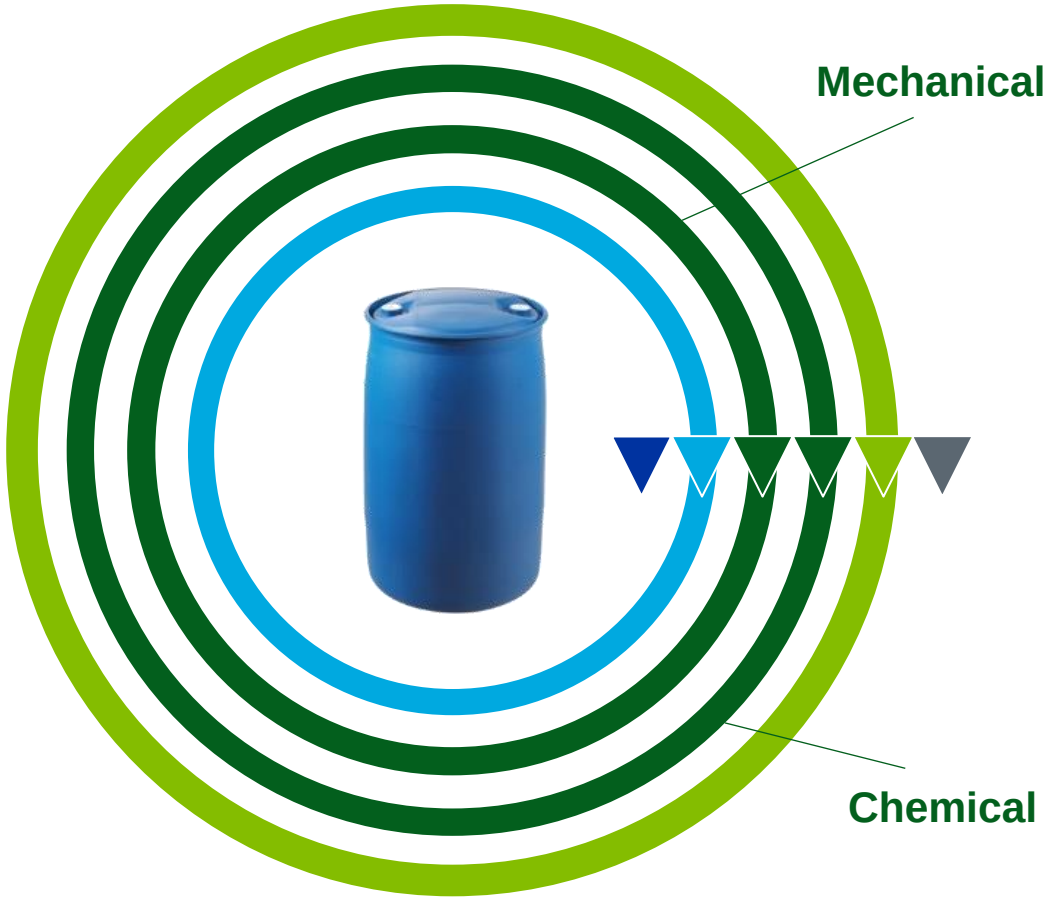


Source: Directive 2008/98/EC on waste (Waste Framework Directive)
http://ec.europa.eu/environment/waste/framework/index.htm

Hierarchy of resource efficiency

Levels are linked to each other – Practicability depending on material & application





Mechanical recycling
MPS Recolene™ - High quality PCR from industrial packaging

Sort	Packaging	Know the history
	MPS Return Criteria	Exclude critical hazards
	ISO 16103:2005	Sorting criteria for recyclates to be used in DG packaging
Grind & Wash	Shredding	Prepare packaging or bales for grinding
	Grinding	Volume reduction and surface increase
	Washing	Remove sticking residues
	Drying	Prepare proper extrusion / granulation process
Granulation	Extrusion	Homogenize material & additives
	Degasing	Remove volatile organic contamination (VOCs)
	Granulation	Prepare proper injection & blow molding

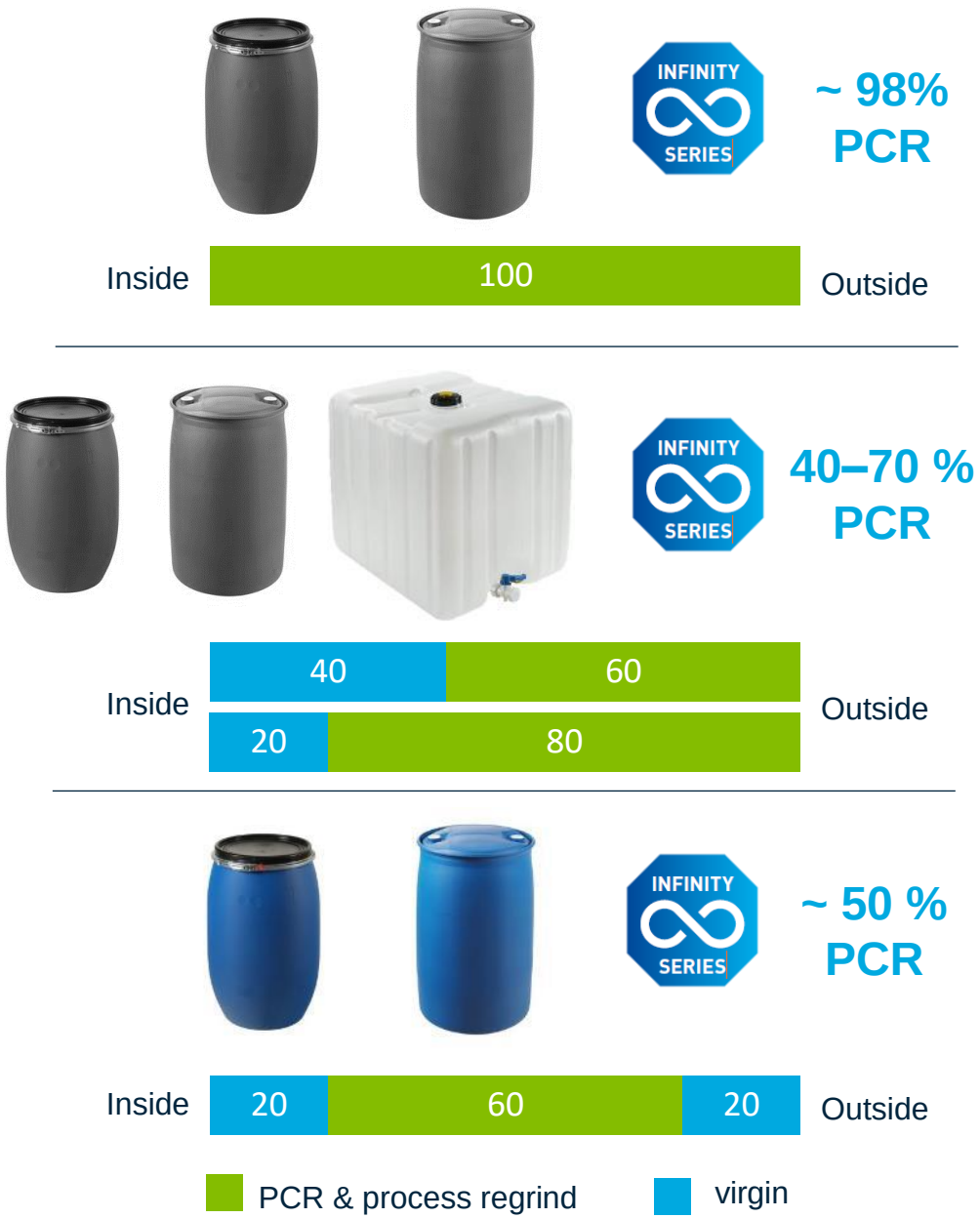
MPS Infinity Series™ -

Industrial packaging from recycled plastics

- Monolayer structure made from up to ~98% recycled plastics – **noUN & UN-certified (limited)**
- 2-layer structure with inner layer from virgin HDPE – reduced risk of potential cross-contamination – **noUN & UN-certified**
- 3-layer structure with inner and outer layer from virgin HDPE – reduced risk of any potential cross-contamination + outer finish like virgin. Middle layer encapsulated – less risk of smell. – **noUN & UN-certified**

Challenges raised by end user market

- ► Appearance: Smell, Color….
- ► Proof on risk of cross-contamination or absence of substances
- ► Sensitive performance applications, e.g. food contact



Why chemical recycling

Chemical recycling to complement mechanical recycling

“While mechanical recycling should remain the preferred choice, it is not technically feasible to recycle some types of plastic waste using this technology or to produce enough high-quality recycled plastics for certain complex applications.” *(Plastics Europe, Plastics – the facts 2022)*

Chemical recycling can produce recycled plastics from hard-to-recycle waste, such as

1. Plastics from mixed waste, e.g. multilayer packaging, automotive or electronic shredder residues
2. Thermosets Plastics, e.g. polyurethane mattresses, fridge insulation
3. Contaminated Plastics, e.g. contaminated industrial packaging & waste containing restricted or legacy substances, which need to be extracted

Chemical recycled plastics is highly suitable for complex end-applications which is not always possible with mechanically recycled materials, such as

a. food contact and medical applications
b. safety- & performance-critical applications (such as automotive)

Source: Plastics Europe - https://plasticseurope.org/wp-content/uploads/2023/08/ChemicalRecyclingOne-pagers_APPROVED.pdf

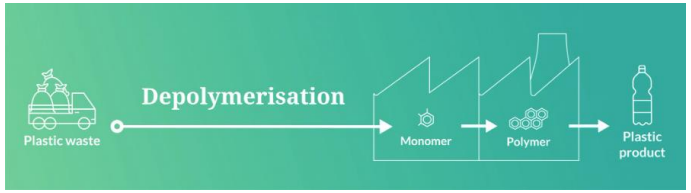
How does chemical recycling work?

The three main recycling routes in chemical plastics recycling.

Plastic recycling starts with an initial step where plastic waste is sorted / screened and prepared for further processing.

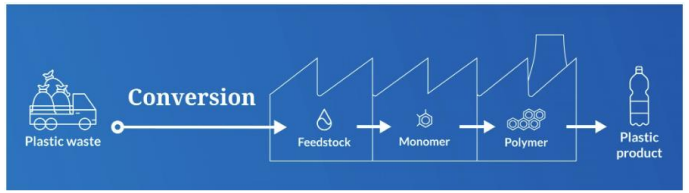
‘Dissolution’ / ‘Solvent based purification’ / ‘Solvent based extraction’ - Sorted plastic waste is dissolved to extract the polymers and make new recycled plastic from them.

The dissolution process uses some heat and solvents to dissolve plastic into a solution of polymers and additives that it was originally made from. During the dissolution process the structure of the polymer is not altered. In a final step, new additives are added to polymers to produce the new recycled plastic.



‘Depolymerisation’ / ‘Chemolyis’ / ‘Solvolysis’ - Sorted plastic waste is broken down into monomers to feed them back into the plastic production.

The depolymerisation process uses different combinations of chemistry, solvents and heat to break down polymers into monomers. The monomers are then fed back into the normal plastic production processes as a secondary raw material. The plastics produced this way are of similar quality than those made from traditional fossil resources.



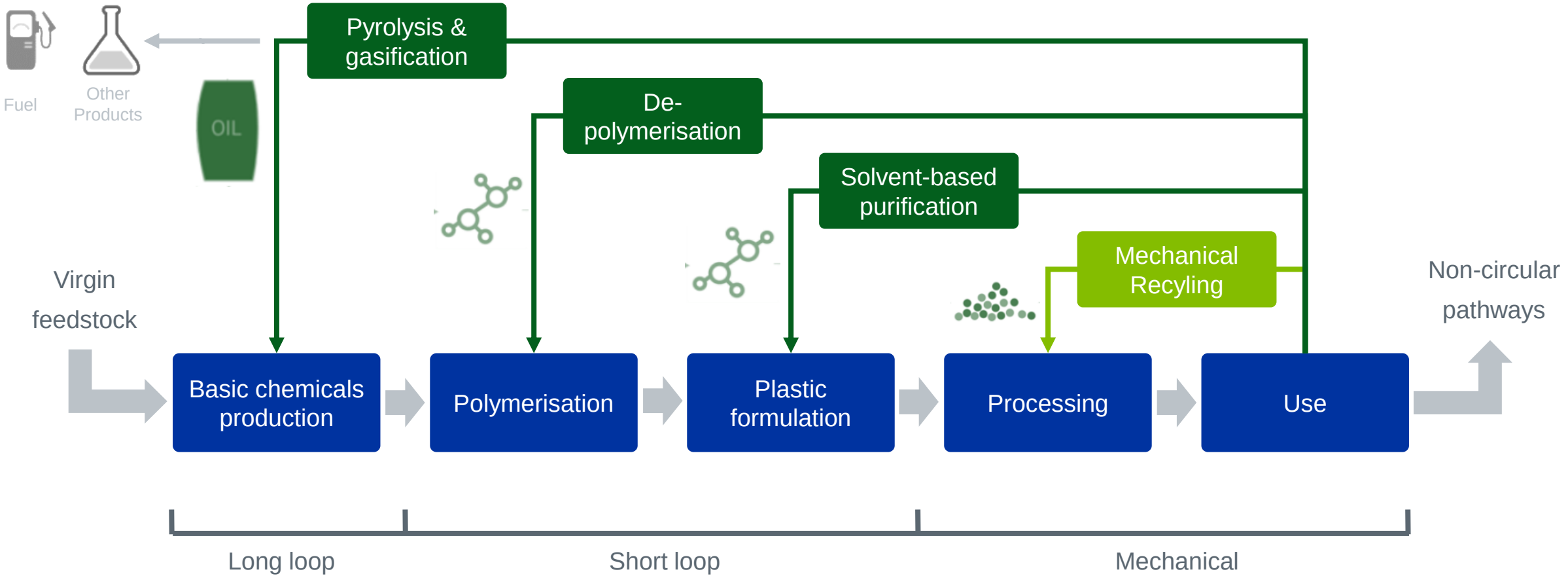
‘Conversion’ / ‘Pyrolysis’ / ‘Gasification’- ‘Mixed’ plastic waste is broken down into oil- or gas-like feedstock used to produce chemicals including plastics

The conversion process uses heat and chemistry in a reactor to break down the plastic waste into either a liquid, oil like feedstock (pyrolysis) or gaseous feedstock (gasification). The produced feedstock (re)enters the chemical production chain at the refinery or cracker level as secondary raw material replacing newly extracted fossil feedstock. The resulting products are used to manufacture chemicals including plastics of similar quality than those made from traditional fossil resources.

Source: : https://cefic.org/a-solution-provider-for-sustainability/chemical-recycling-making-plastics-circular/chemical-recycling-via-dissolution-to-plastic/

Plastic recyclates

Production steps of recyclates for different recycling techniques (CE Delft, 2019)*



Source: CE Delft, 2019. Chemische recycling in het afvalbeleid, Delft: CE Delft. / CE Delft, April 2023, Impacts of allocation rules on chemical recycling, Delft: CE Delft

Effectiveness of different plastic recycling techniques

Plastic-to-plastic yield (P2P yield)

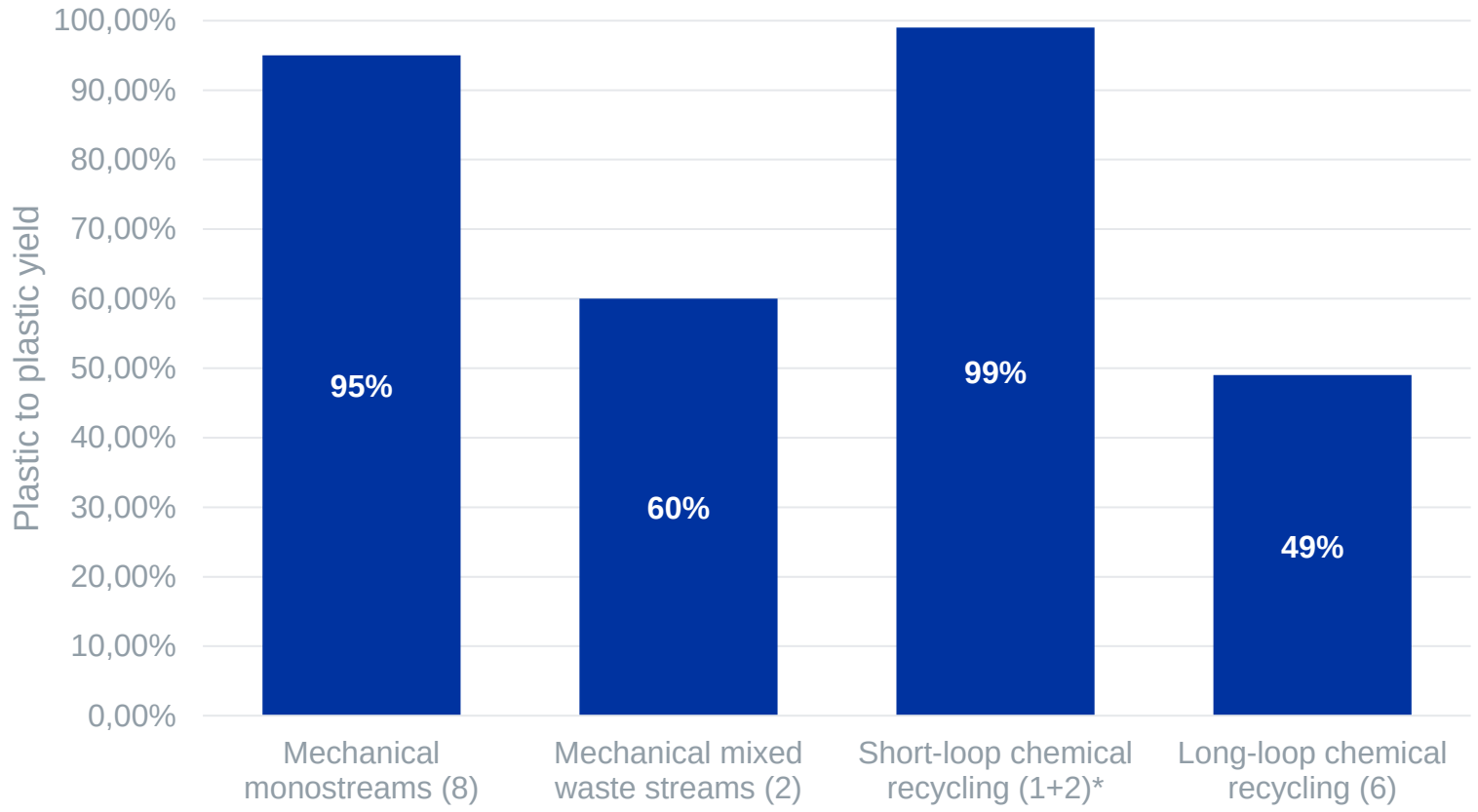
The P2P yield quantifies the amount of new plastics that can be produced from plastic waste sent to recycling.

$$\boldsymbol{Plastic-to-plastic\ yield}\ (\%) = \frac{\boldsymbol{Recycled\ plastic\ entering\ compounding\ (by\ weight)}}{\boldsymbol{Plastic\ sent\ to\ recycling\ (by\ weight)}}$$

These P2P yields determine (alongside the sorting and separation yields) how efficiently plastic waste can be transformed to recyclate.

Effectiveness of different plastic recycling techniques

Plastic-to-plastic yield (P2P yield) – Estimates by CE Delft



Based on questionnaires returned by industry and subsequent discussions with companies, CE Delft prepared an overview of the plastic-to-plastic yield estimates for different processes.

Number in brackets links to questionnaires evaluated per recycling technique.

* Refers to Solvent-based extraction of PS and Depolymerisation of PET

Source: CE Delft, April 2023, Impacts of allocation rules on chemical recycling, Delft: CE Delft / : CE Delft, March 2022, Monitoring chemical recycling – How to include chemical recycling in plastic recycling monitoring, Delft: CE Delft

Chemical recycling – capacity estimate EU

Commitments of member companies of Plastics Europe

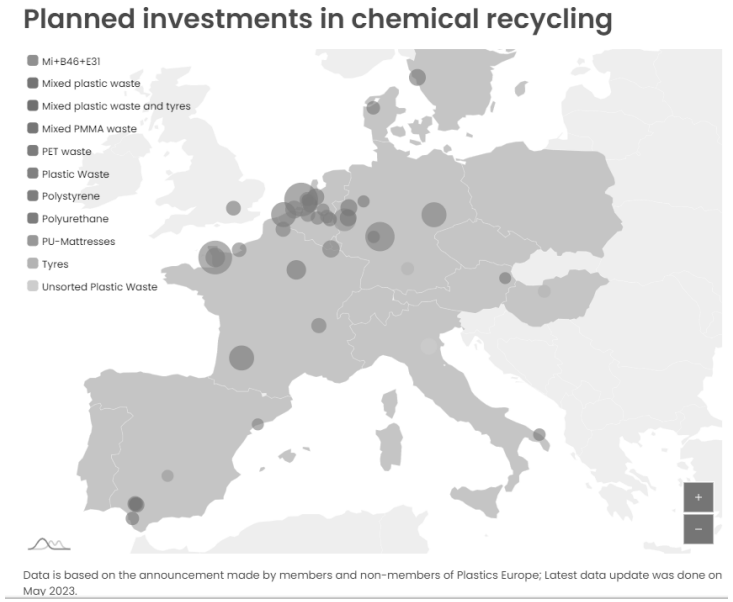
PLASTICS EUROPE
Enabling a sustainable future

44 projects

13 countries

€8 bn invest

2.8 mt output



Country	Location	Feedstock	Capacity [t input/a]
Austria	Swechat	Mixed plastic waste	800
Belgium	Ostende	Mixed plastic waste	120.000
Denmark	Skive	Mixed plastic waste	16.000
Finnland	Kilpilahti	PET-waste	10.000
France	Damazan	Mixed plastic waste	120.000
France	Crancey	Mixed plastic waste	70.000
France	Saint-Maurice-de-Beynost	PET-waste	30.000
France	Longlaville	PET-waste	Pilot
France	Wingles	PET-waste	30.000
France	Le Havre	Polyurethane	25.000
France	Normandie	Polyurethane	200.000
France	Normandie	Polyurethane	70.000
Germany	Cologne	Mi+B46+E31	100.000
Germany	Ennigerloh	Mixed plastic waste	2.500
Germany	Gelsenkirchen	Mixed plastic waste	not specified
Germany	Leverkusen	Mixed plastic waste	Pilot
Germany	Hanau	PET-waste	160.000
Germany	Boehlen	Polyurethane	120.000
Germany	Dillingen	Tyres	10.000
Hungary	Budapest	Tyres	9.000
Italy	Brindisi	Mixed plastic waste	6.000
Italy	Ferrara	Unsorted Plastic Waste	Pilot
Netherlands	Maasvlakte	Mixed plastic waste	200.000
Netherlands	Mordejk	Mixed plastic waste	30.000
Netherlands	Geleen	Mixed plastic waste	20.000
Netherlands	Utrecht	Mixed PMMA waste	not specified
Netherlands	Vlissingen	Plastic waste	55.000
Netherlands	Rotterdam	Plastic waste	40.000
Netherlands	Antwerp	Plastic waste	65.000
Netherlands	Tesenderlo	Polystyrene	15.000
Netherlands	Eindhoven	Polystyrene	7.000
Netherlands	Brightlands	Polystyrene	15.000
Spain	Sevilla	Mixed plastic waste	33.000
Spain	Andalucia	Mixed plastic waste	30.000
Spain	Jerrez	Mixed plastic waste & tires	15.000
Spain	Tarragona	Polyurethane	2.000
Spain	Puertollano	PU-Matresses	2.000
Sweden	Stenungsund	Mixed plastic waste	not specified
UK	London	Mixed plastic waste	27.000

Source: Plastics Europe - https://plasticseurope.org/sustainability/circularity/recycling/chemical-recycling/

Feedstock for plastics recycling

The Circular Economy for Plastics – A European Overview (Plastics Europe)

Stage	Quantity [Mt]	'Loss' / 'Potential' [Mt]
Consumption	53,6	
Products in Use		-24,1
Waste	**29,5**	
Waste to Landfill		-6,9
Waste to Energy Recovery		-12,4
Waste to Recycling	10,2	
Waste to Recycling (Export)		-1,1
Input into Recycling Plants	9,1	
Process Loss Recycling Plants		-3,6
PCR (Output)	**5,5**	

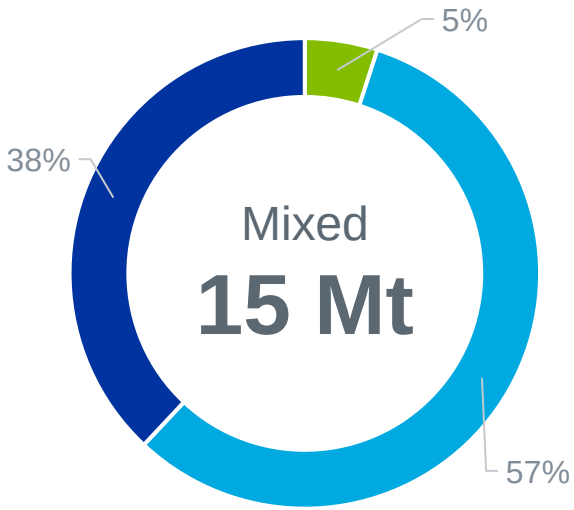
Source: Plastics Europe, The Circular Economy for Plastics – A European Overview, Edition 2022

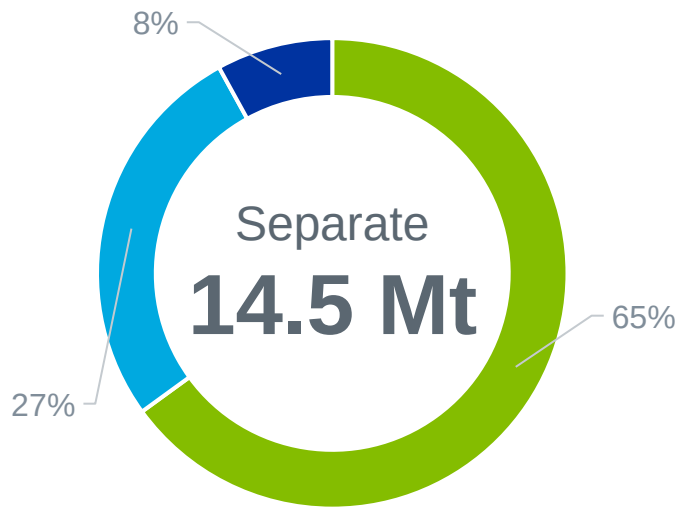
Levers for increase of plastics recycling input

Separate waste collection to increase recycling rates

Plastics

29.5 Mt



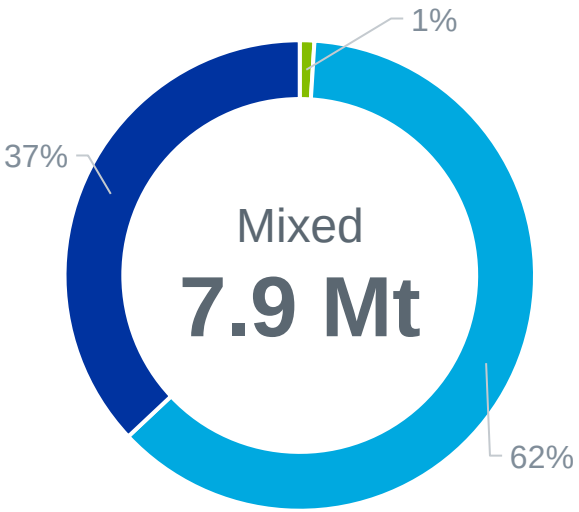


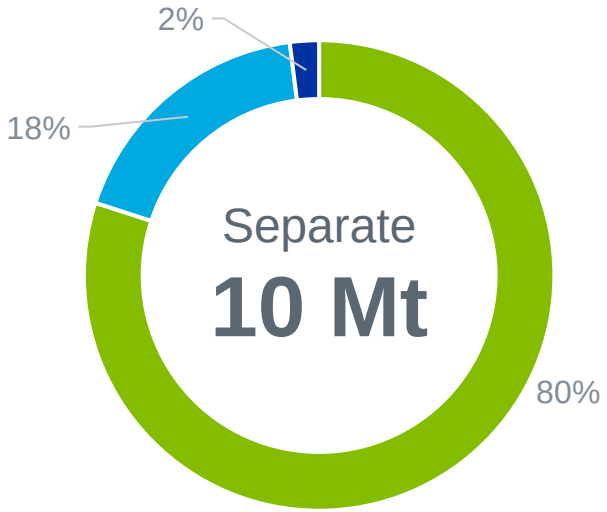
Waste recycling rates higher when collected separately

13x

Plastics Packaging

17.9 Mt





80x

Source: Plastics Europe, Plastics – the Facts 2022, October 2022
Data reference year: 2020

Where does chemical recycling fit into industrial packaging?

Cascaded Reuse & Recycling

Thesis:

Chemical recycling resp. the use of chemically recycled plastic materials **not to be a large scale circular plastic solution in the field of industrial packaging** in a foreseeable timeframe.

- High investment need, to be established industrial scale infrastructure
- Limited capacities absorbed by other demanding markets, e.g. food contact / cosmetic / pharma consumer packaging

But **a needed complimentary approach** potentially capable to

- Make use of pre-sorted contaminated plastic waste streams currently going into energy recovery
- To be used with plastic components / auxiliaries in direct filling good contact, e.g. closures, coatings
- To be used with selected high performance DG packaging (PGI)

Summary

- Mechanically recycled plastics / PCR with proven track record to perform in industrial packaging
- Further process improvement, capacity buildup & regulatory adaption needed for increased circularity
- Cascaded reuse / recycling in industrial packaging valuable fundament for high quality & cost efficient circularity
- Chemical recycling in industrial packaging with complementary potential concerning
  - Challenging plastic waste streams currently going to energy recovery
  - Removal of (historical) substances of concern, technically not to be removed by mechanical recycling
  - Selected contact sensitive / performance applications, e.g. closures, coatings
- Chemical recycling complementary, but no stand-alone solution - challenging feedstock situation, low process yield (t plastic generated per t plastic waste), high investment cost and restricted availability
- Legislative framework for tracking recycled content, carbon emission etc. with chemically recycled materials work in progress - industrial packaging industry to track, these (e.g. mass balance) not to down reuse & mech. recycling

Chemical recycling no comprehensive, but a potentially future complimentary solution to cascaded reuse / mechanical recycling of plastics in Industrial Packaging.

Thank you
for your attention.