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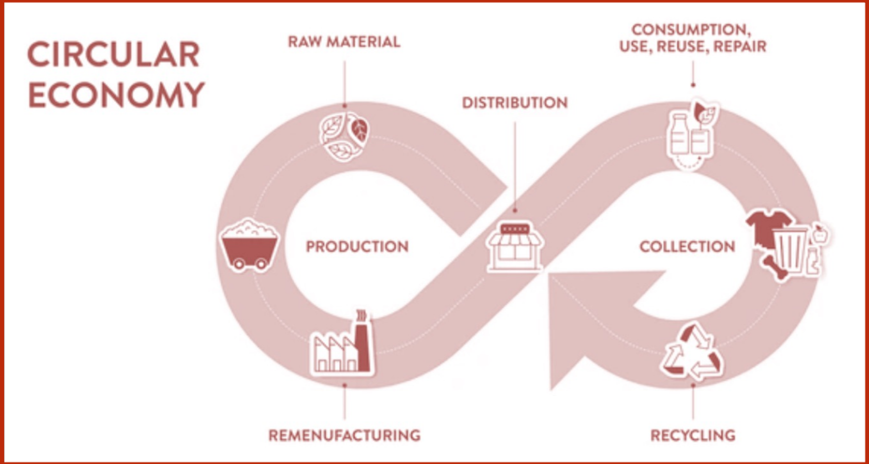

Le diverse declinazioni della sostenibilità per il settore manifatturiero: focus sul mondo della plastica

Fabbrica Futuro Bologna, 14th june 2024

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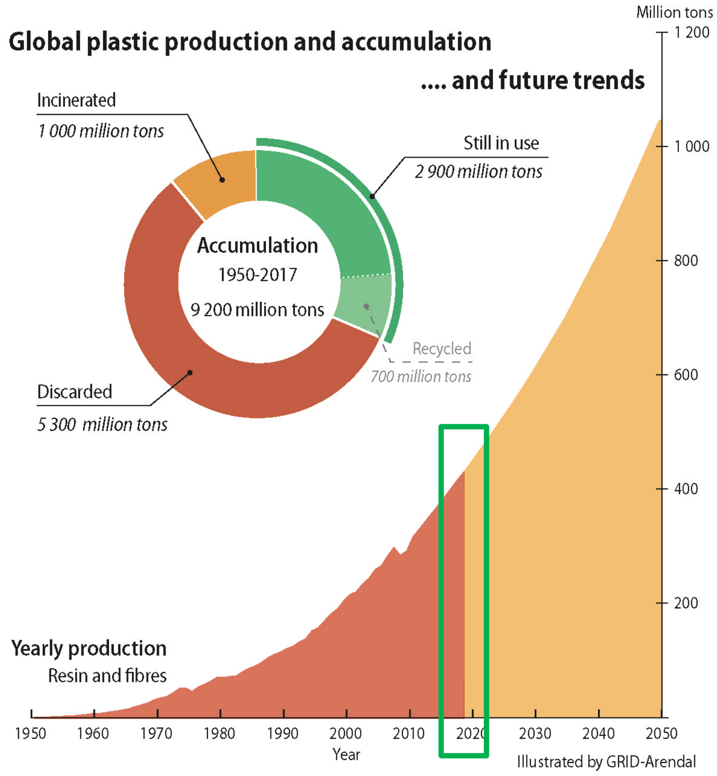
Unibo is member of the
European Bioplastics Association

- Plastics have become the ubiquitous workhorse material of the modern economy – combining unrivalled functional properties with low cost.

Plastics and Plastic Packaging Are an Integral and Important Part of the Global Econc



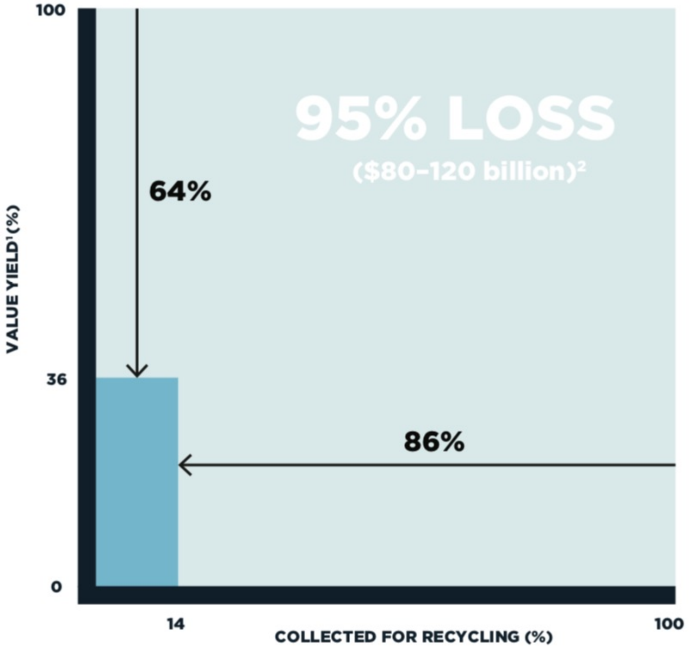
UNEP (2021). From Pollution to Solution: A global assessment of marine litter and plastic pollution. Nairobi.

Figure 2: Main Plastic Resin Types and Their Applications in Packaging

Plastic packaging is an iconic linear application with $80–120 billion annual material value loss

After a short first-use cycle, **95% of plastic packaging material value**, or $80–120 billion annually, **is lost** to the economy

Figure 3: Plastic Packaging Material Value Loss after One Use Cycle



1 Value yield = volume yield * price yield, where volume yield = output volumes / input volumes, and price yield = USD per tonne of reprocessed material / USD per tonne of virgin material

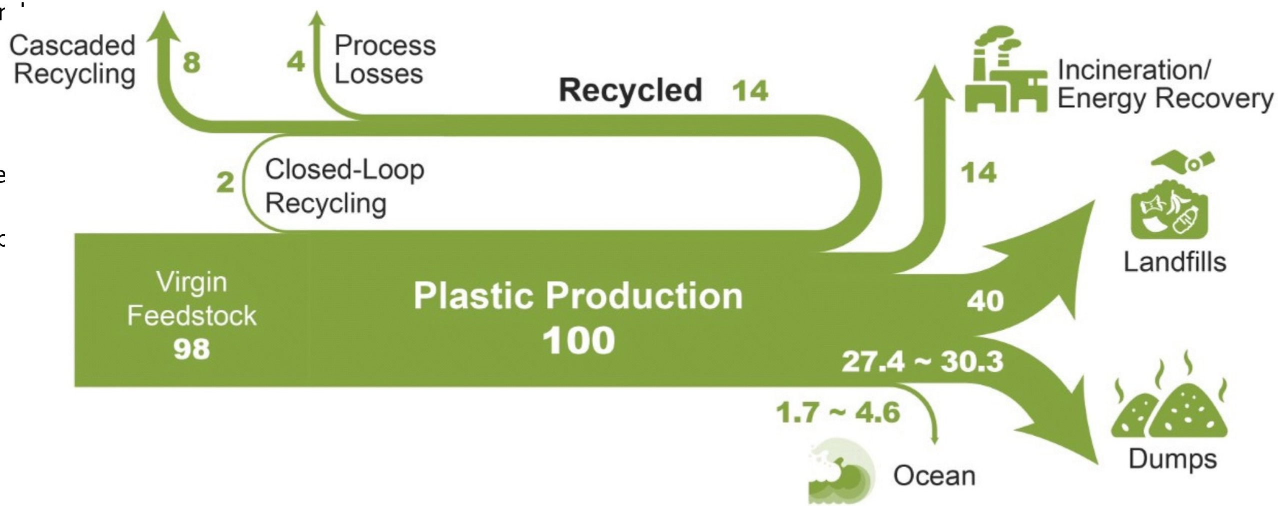
2 Current situation based on 14% recycling rate, 72% volume yield and 50% price yield. Total volume of plastic packaging of 78 Mt, given a weighted average price of 1,100–1,600 USD/t

Source: Expert interviews; Plastic News; Deloitte, Increased EU Plastics Recycling Targets: Environmental, Economic and Social Impact Assessment – Final Report (2015); The Plastics Exchange; plasticker; EUWID; Eurostat

Plastics and packaging generates significant negative externalities

32% of plastic packaging **escapes collection** systems generating significant economic costs by reducing the productivity of vital natural systems such as the ocean ar clogging urban infrastructure.

The cost of such after-use externalities for plastic packaging, plus the cost associated with greenhouse gas emissions from its production, is conservatively estimate at $40 billion annually – exceeding the plastic packaging industry’s profit pool. In future, these costs will have to b covered.



Current innovation and improvement efforts fail to have impact at scale

- Many innovation and improvement efforts show potential, but to date these have proven to be too fragmented and uncoordinated to have impact at scale.

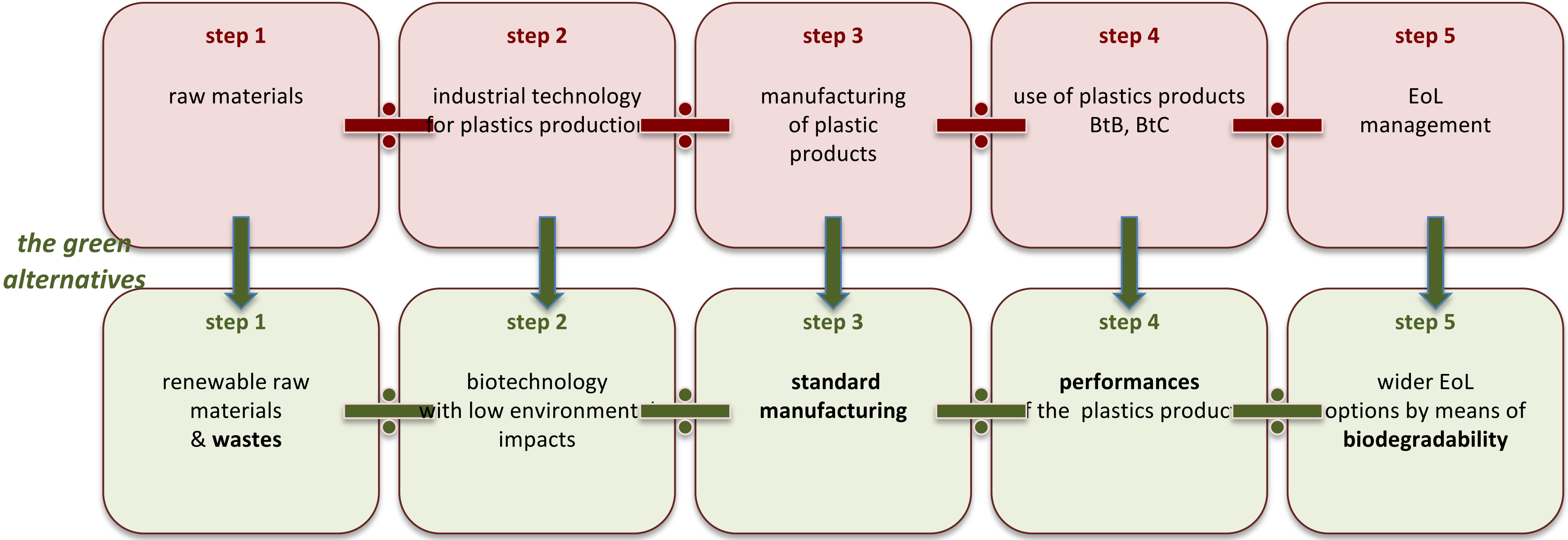
- The **lack of standards and coordination** across the value chain has allowed the proliferation of materials, formats, labelling, collection schemes, and sorting and reprocessing systems, which collectively hamper the development of effective markets.

- **Innovation is also fragmented**.

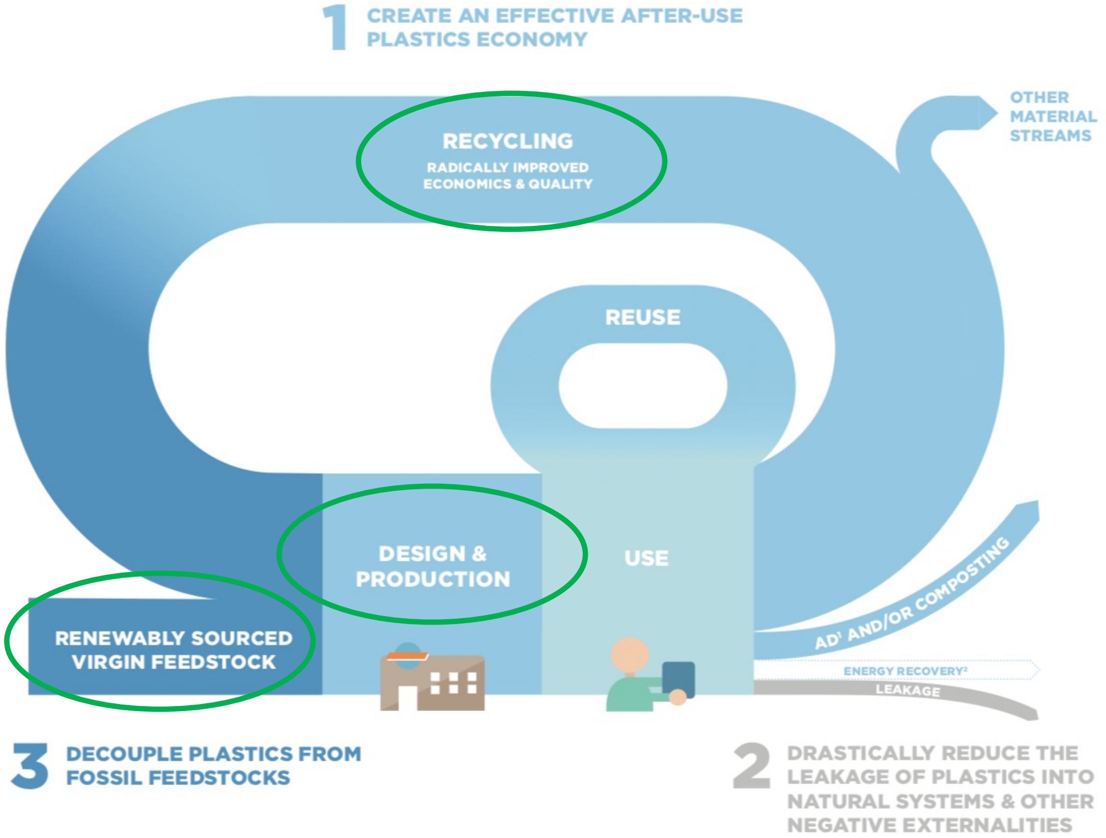
- The development and introduction of new packaging materials and formats across global supply and distribution chains is happening far **faster** than and is **largely disconnected** from the development and deployment of corresponding **after-use systems and infrastructure**.

BUT : what does SUSTAINABILITY mean for the plastic products?

if we want to go for a SUSTAINABLE DEVELOPMENT of the plastic packaging sector,
we need to look for SUSTAINABILITY in EVERY stage of the plastic products' life cycle.



from LINEAR to CIRCULAR plastic economy



1 Closed-loop recycling: Recycling of plastics into the same or similar-quality application

2 Cascaded recycling: Recycling of plastics into other, lower-value applications

Source: Project Mainstream analysis – for details please refer to the extended version of the report available on the website of the Ellen MacArthur Foundation: www.ellenmacarthurfoundation.org

ReShaping the European Plastics System

Scenario	Scenario description	Key Assumptions
Current Actions Scenario	All major commitments already made by the public and private sectors until 2020 are implemented and enforced These include European regulation and voluntary industry commitments	• Current regulation (as of April 2021) is implemented and enforced • No additional regulation is put in place • Voluntary commitments are met in full • Basel convention strengthens and international waste trade is increasingly controlled and regulated
Reduction & Substitution Scenario	Reduction of plastic use through elimination, ambitious introduction of reuse and new delivery models, and plastic substitutions where it makes sense	• Strong policy intervention to incentivize reuse, new delivery models and DRS • Investment into reuse and new delivery models infrastructure, including reverse logistics, and technological improvements • Wide consumer and business adoption of these models • Performance & cost improvements of compostables and other substitutes
Recycling Scenario	Ambitious expansion and investment into collection for recycling, sorting, mechanical recycling, and chemical recycling infrastructure	• All plastic packaging is designed for recycling • Supportive policy incentives including minimum recycled content, recycling targets, EPR and more • Financial investment into recycling investment and R&D • Chemical recycling scales across Europe from its low base today
Circularity Scenario	All circularity levers are applied concurrently and ambitiously, including both upstream (see Reduction & Substitution Scenario) and downstream (see Recycling Scenario)	• All "Recycling Scenario" and "Reduction & Substitution Scenario" conditions are met concurrently • Consumers are educated, engaged and change behaviours regarding consumption and waste management
Retrofit System Change Scenario	On top of Circularity Scenario, assumes the substitution of carbon intensive fuels with low-carbon hydrogen and the capture and storage of CO_2 emissions from plastic manufacturing and incineration	• Affordable and abundant low-carbon hydrogen is available at ~€2/kg • CCS technologies scale and are affordable in multiple geographies • Methanol to olefins capabilities are available (commercially) to upgrade steam cracking off-gasses • Chemical recycling can improve its carbon profile
Net-Zero System Change Scenario	On top of Retrofit Scenario, assumes expansion of the role of hydrogen, the use of alternative feedstocks from both biological sources and CO_2 capture, and electrification of some steam crackers	• Carbon usage technologies reach maturity and affordability • Sufficient quantities of sustainable biomass is available for plastics • Electrification of steam cracking technical barriers can be overcome • GHG reduction can be applied to chemical recycling

2050 ENDSTATE Scenario	Circularity (%)	GHG Emissions ($MtCO_2e$)	Virgin Fossil Plastic Use (Mt)
Base Case (Current System)	14%	112	44
Current Actions Scenario	33%	92	37
Reduction & Substitution Scenario	52%	68	29
Recycling Scenario	69%	41	24
Circularity Scenario	78%	33	20
Retrofit System Change Scenario	78%	25	20
Net-Zero System Change Scenario	78%	~0	11

FAST FACTS

ReShaping Plastics in numbers

State of Play Today

24.5 million tonnes
of **plastic waste generated** in 2020

14%
of **plastic waste were recycled**, providing 3.5 Mt of recyclates in 2020

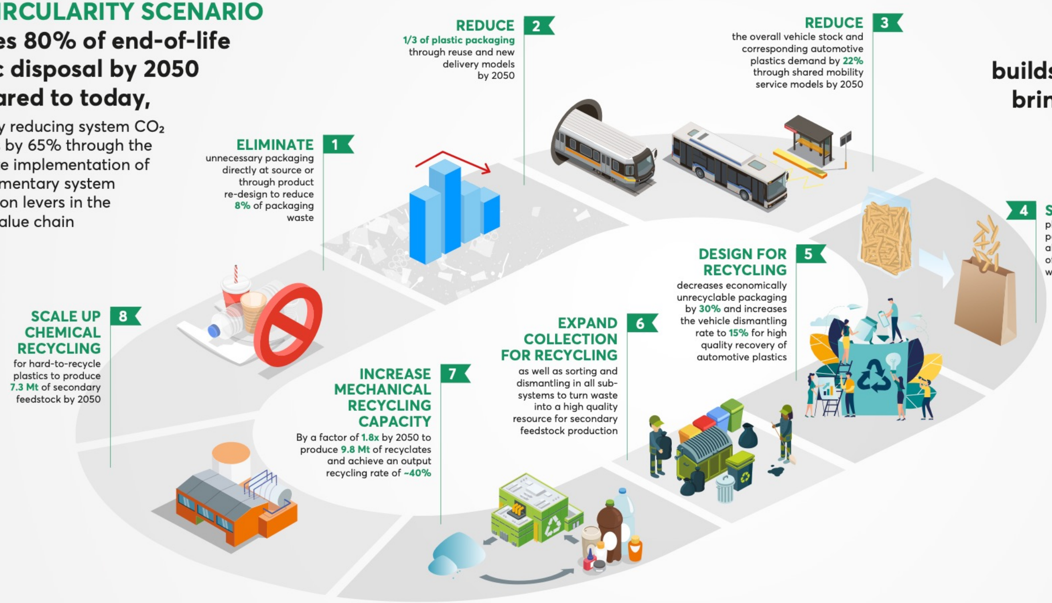
50%
of today's European plastic waste is **incinerated for energy recovery**

95 million tonnes
of **CO_2e are emitted per year** in 2020, one-third is caused by incineration

8-15 million tonnes
of **unaccounted for plastic** as a result of gaps in waste data

The CIRCULARITY SCENARIO reduces 80% of end-of-life plastic disposal by 2050 compared to today,

effectively reducing system CO_2 emissions by 65% through the immediate implementation of 8 complementary system intervention levers in the plastics value chain



The NET ZERO SYSTEMS CHANGE SCENARIO builds on the Circularity Scenario and brings the European Plastics system on a net zero pathway through 4 methods of GHG reduction:

A — CHANGE THE FEEDSTOCK CARBON SOURCE
to provide 1/4 of feedstock by 2050 via sustainable bio-based materials or captured carbon and hydrogen

B — APPLY BLUE AND GREEN HYDROGEN
as fuel and feedstock to reduce production emissions

C — ELECTRIFY HEAT SOURCES
for steam crackers with cumulative production capacity of 1.5 million tonnes by 2050

D — CAPTURE PRODUCTION AND END-OF-LIFE EMISSIONS
through applying CCS to steam crackers or CCU/S to waste-to-energy plants

The NET ZERO SYSTEMS CHANGE SCENARIO achieves environmental and economic benefits

Target State 2050

-60%
(255 Mt) less waste incinerated between 2020-2050

>70%
less virgin plastic produced from fossil fuels

1.6 Gigatonnes
cumulative CO_2 emissions saved between 2020-2050

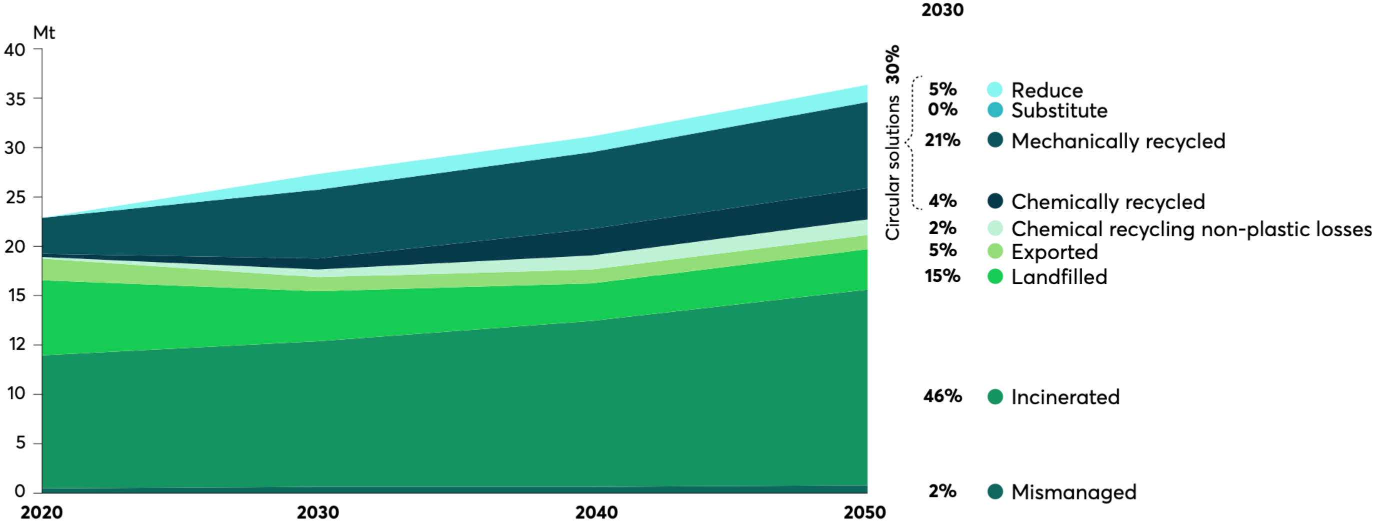
+160,000
jobs from circularity levers

1 in 4€
to be redeployed to innovative low carbon technologies and circular business models

The European plastics system is adapting to address the challenges described in the previous section, but it is not happening fast enough to align with societal expectations or European climate commitments. Ambitious actions from industry and governments in Europe are building momentum towards system circularity from 14% to 30% by 2030, and driving a 11% decrease in GHG emissions from the plastics system and a 5% reduction in system cost. By 2030, this Current Actions Scenario could reduce plastic entering waste streams by 5%, increase the share of waste being effectively recycled to 27%, minimize exports, and curtail some growth in waste incineration.

Current Actions increase the share of circular solutions to 30% by 2030, up from 14% today

Physical fate of plastic waste from packaging, household goods, automotive, and construction (Mt)

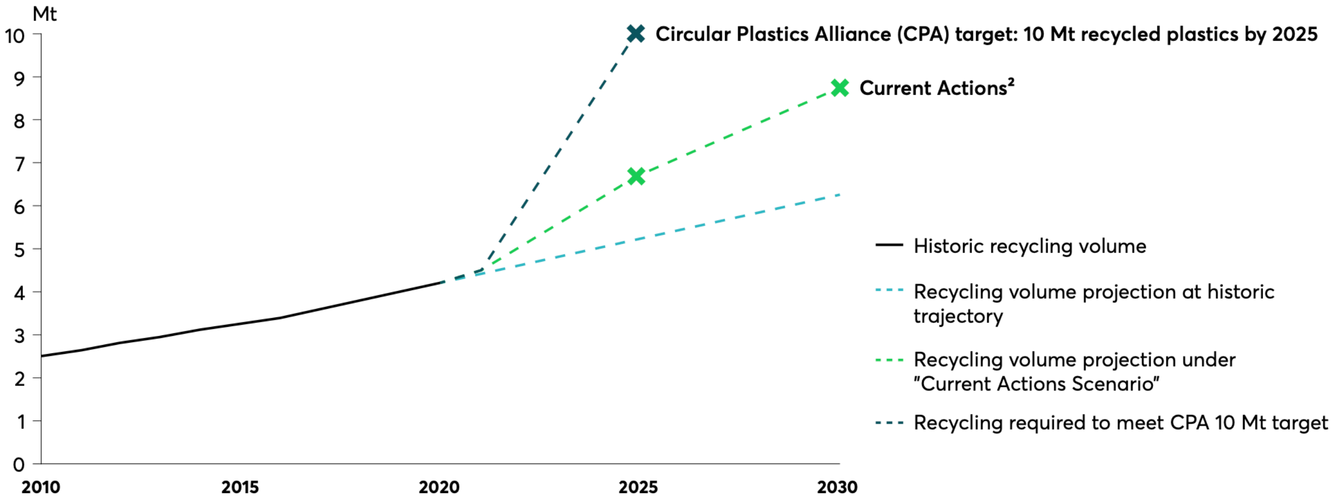


Source: "ReShaping Plastics" model

While these are all positive developments, the pace of change is not yet fast enough to align with the goals of the Circular Plastics Alliance, the European Green Deal, or the Paris and Glasgow climate agreementsxxxi. Meeting these commitments will require an unprecedented effort on behalf of industry, regulators, and other stakeholders; the system is currently not on track to achieve this by 2025

Trajectories are not on track to meet current policy and industry actions and even these actions fall short of the CPA target

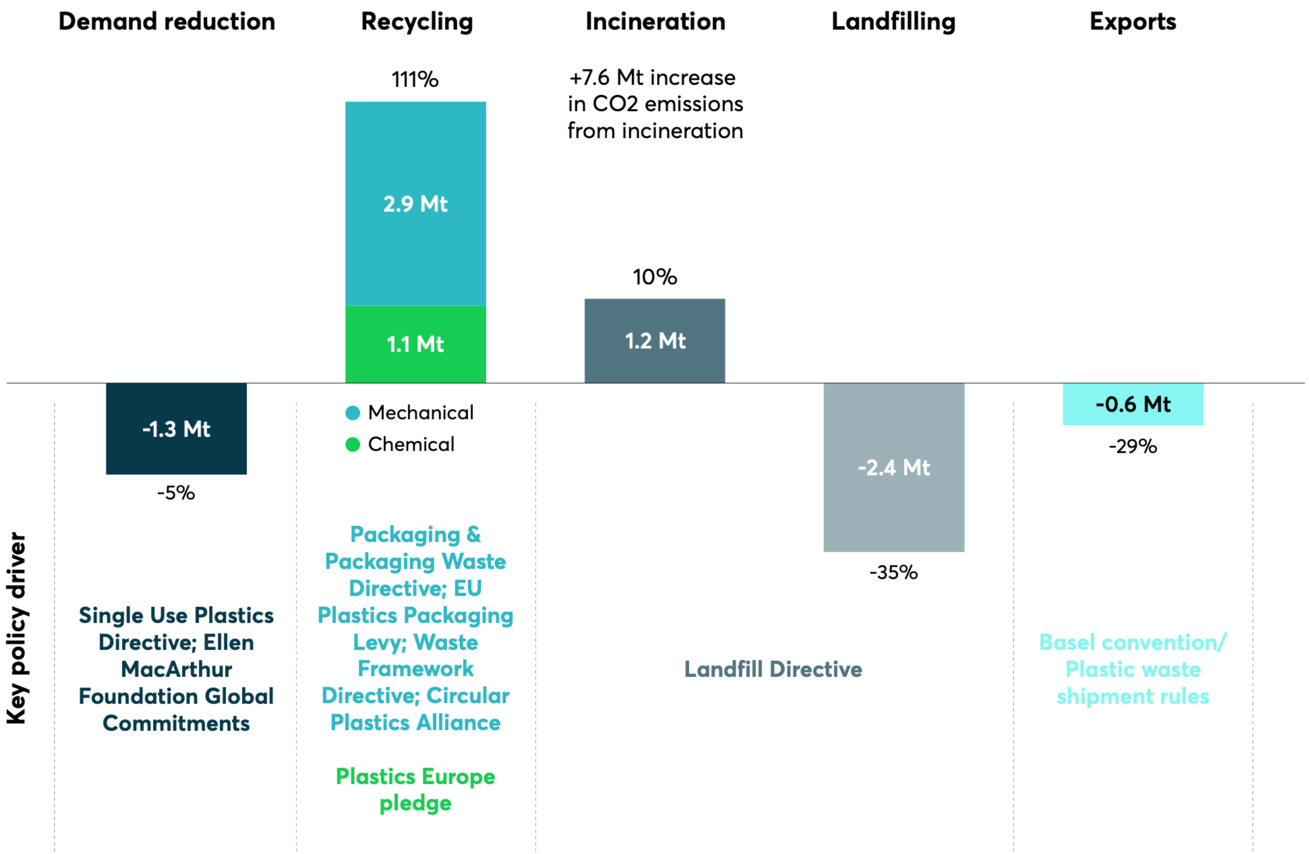
Historic and future projection of recycled plastics in the full system[1] along historic trajectory, to meet current actions and the CPA target (Mt)



Notes: [1] These projections are extrapolated for the entire European plastics system (EU 28 + 2), including all sectors for easy reference for readers familiar with full system numbers;
[2] Includes PPWD, VinylPlus, EMF, and 1/3 of the Plastics Europe chemical recycling pledge
Source: SYSTEMIQ analysis

Current Actions could decrease exports, reduce demand, increase recycling, and divert waste from landfill to incineration by 2030

Impact of Current Actions in 2030 vs 2020 (volumes (Mt) and %-change)

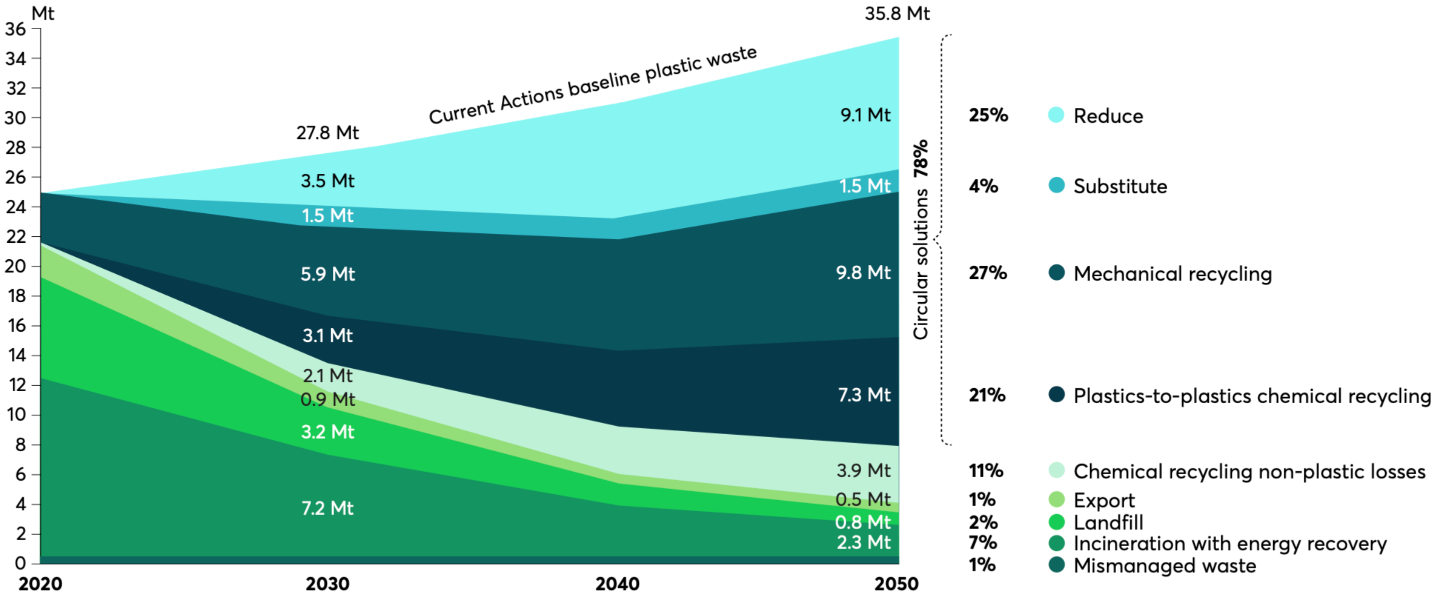


Source: "ReShaping Plastics" model

A Circularity Scenario can change the trajectory

By 2050, the Plastics system could achieve 78% circularity with 30% of waste avoided through reduction and substitution and 48% being recycled, leaving 9% in landfills and incinerators

Physical fate of plastic waste from packaging, household goods, automotive and construction 2020-2050 (Mt)

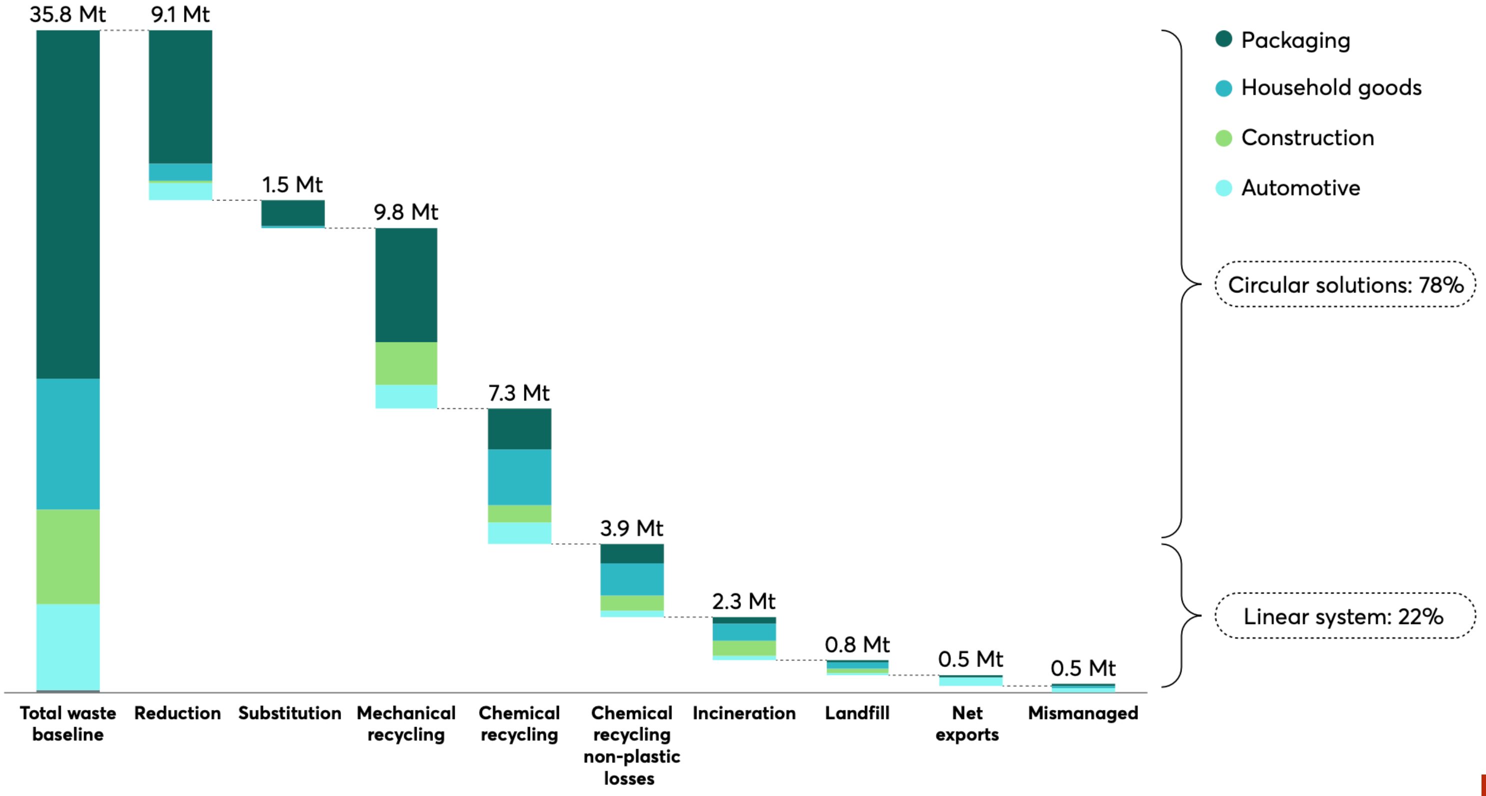


Source: "ReShaping Plastics" model

xlii Defined as the share of plastic utility that is treated in any way other than landfill, incineration with energy recovery, exported, or mismanaged.

By 2050 ambitious application of the circularity levers across the four sub-systems reduces disposal, exports and mismanaged to 22% and increases system circularity to 78%

Physical fate of plastic waste from automotive, construction, packaging and household goods in the circularity scenario in 2050 (Mt)



Note: [1] Chemical recycling non-plastic losses describes gaseous and process losses in chemical recycling (gasification and pyrolysis)
Source: "ReShaping Plastics" model

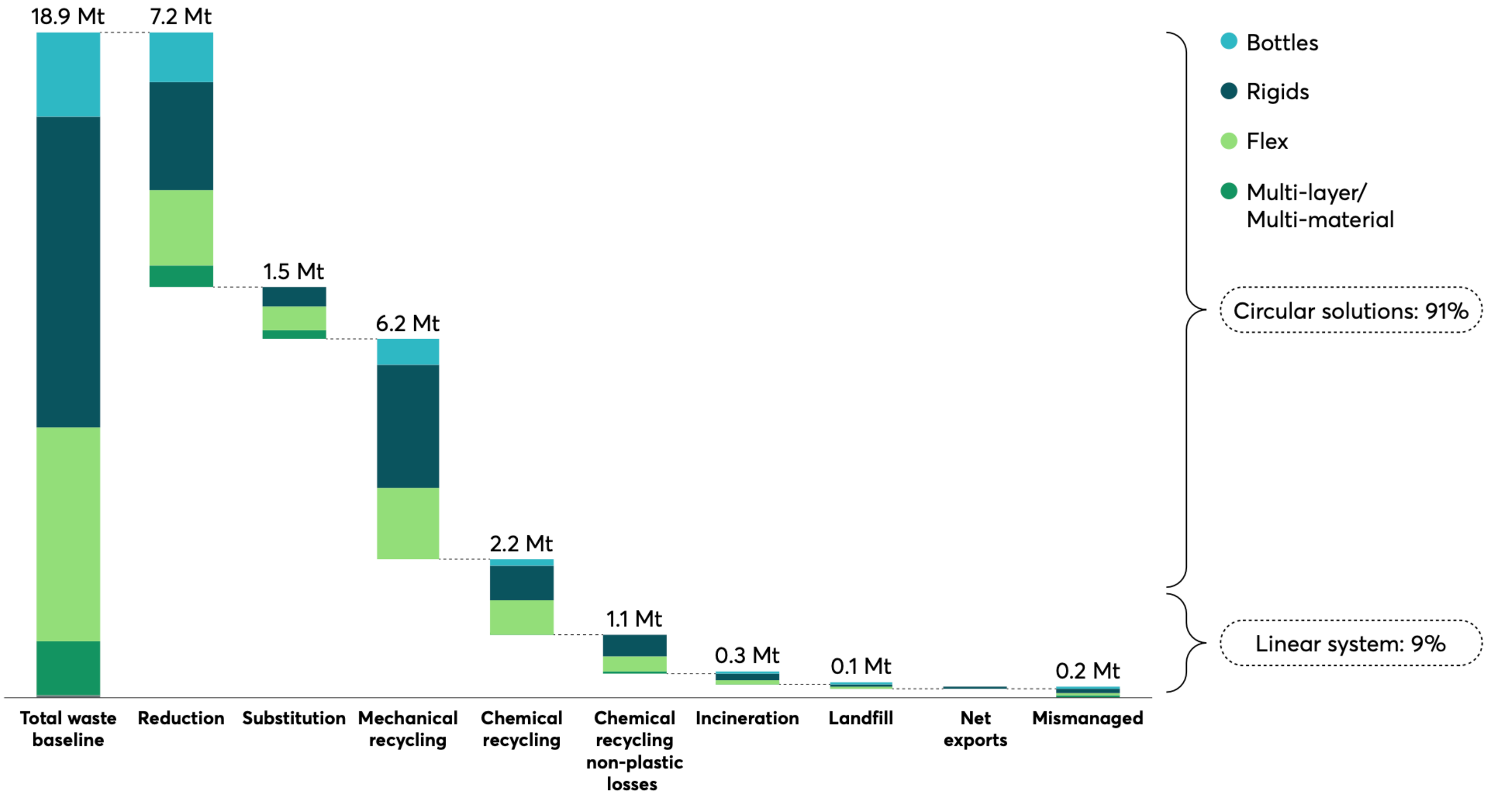
Four system interventions and corresponding levers improve circularity in the sub-systems with varying applicability

✓ Highly applicable ✓ Partially applicable

System Intervention	System Intervention Levers	Plastics sub-system and applicability of intervention				Main responsible stakeholder
		Packaging	Household	Construction	Automotive	
#1 Reduction	Reduce plastic through elimination	Highly applicable	Highly applicable			Consumer goods brands; retailers
	Reduce plastic through reuse/ New Delivery Models	Highly applicable	Partially applicable	Partially applicable	Partially applicable	Consumer goods brands; OEMs; construction companies
	Reduce plastic through sharing models for vehicles				Highly applicable	OEMs
#2 Substitution	Substitute plastic with alternative materials	Partially applicable	Partially applicable			Consumer goods brands; retailers
#3 Mechanical recycling	Design for mechanical recycling	Highly applicable		Highly applicable	Partially applicable	Consumer goods brands; OEMs; construction companies
	Expand collection for recycling and sorting	Highly applicable		Highly applicable	Partially applicable	Local governments
	Increase mechanical recycling capacity	Highly applicable		Highly applicable	Highly applicable	Waste management companies
#4 Chemical recycling	Scale up chemical recycling	Highly applicable	Highly applicable	Partially applicable	Highly applicable	Petrochemical industry

Ambitious application of the circularity interventions in the packaging sub-system increases system circularity to 91%

Physical fate of plastic waste from packaging in the Circularity Scenario in 2050 (Mt)



Note: [1] While today very few flexibles are mechanically recycled, this scenario assumes that mechanical recycling of flexibles will improve with better technology, processes and supportive policy

[2] Chemical recycling non-plastic losses describes gaseous and process losses in chemical recycling (gasification and pyrolysis)

Reduction and Substitution strategies can provide resource-efficient, circular alternatives to Single-Use Plastics Packaging

Reduction of the overall amount of packaging required while functionality and utility are provided

1 Elimination

Practices that reduce unnecessary plastic packaging directly at source or through innovative product design

- **Example 1:** Reduction of secondary packaging and excess headspace
- **Example 2:** Lightweight formats, pouches instead of rigid bottles
- **Example 3:** Packaging-free products and edible coatings

2 Reuse models

Replacement of single-use packages with reusable items owned and managed by the user or by services and businesses which provide the utility (New Delivery Models)

- **Example 1:** In-store refill solutions
- **Example 2:** Reusable food service items (cups, containers)
- **Example 3:** Concentrated capsules subscription services

Use alternative materials that are more circular and sustainable*

3 Substitution

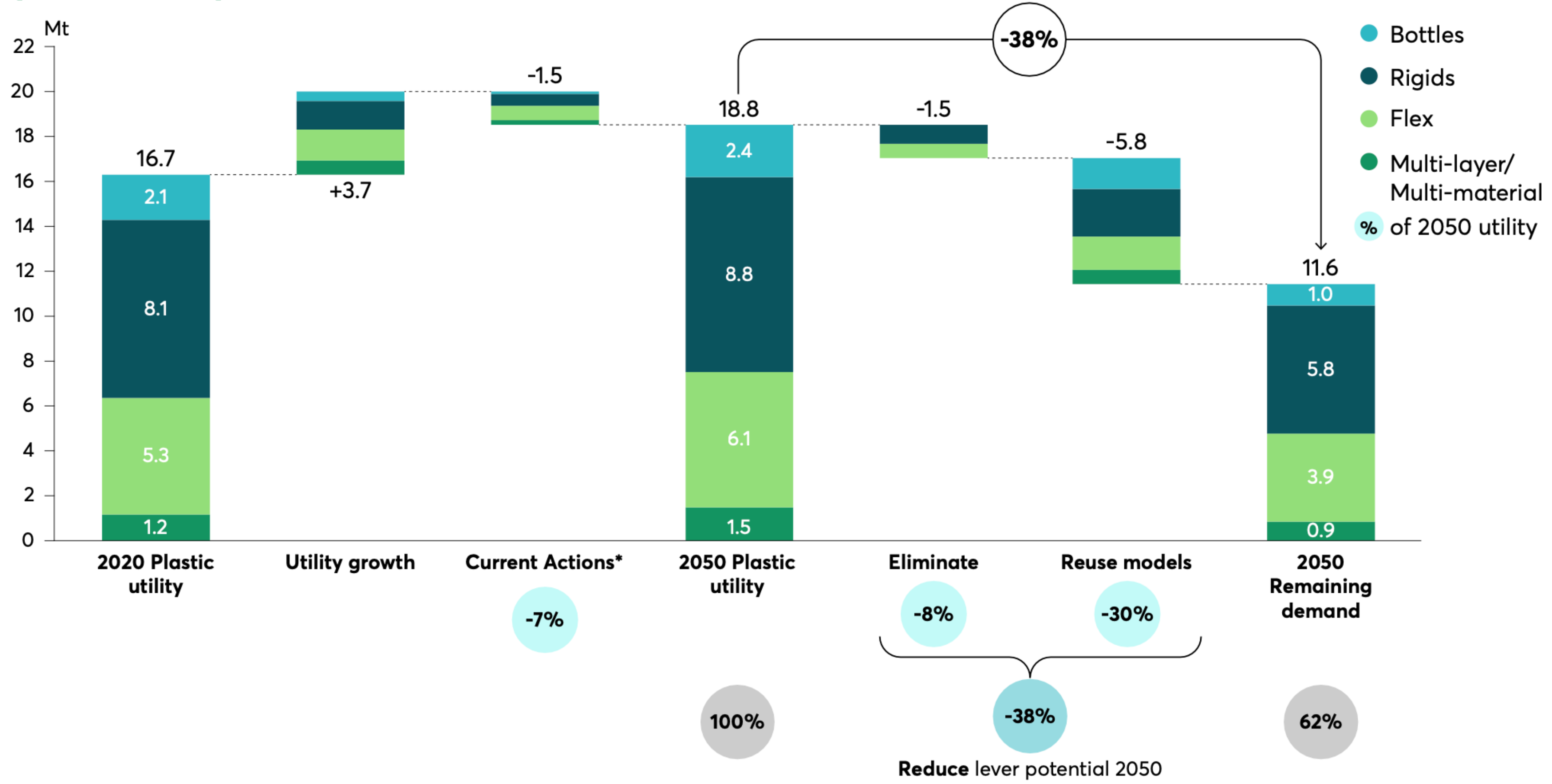
Replacement of plastic by sustainable and circular materials:

- Paper and coated paper (plastic coating 5% of weight)
- Compostable materials capable of disintegrating into natural elements

- **Example 1:** Fibre-based protective packaging
- **Example 2:** Coated paper snack wrappers
- **Example 3:** Compostable ready-meal sauce packets

Note: * To avoid inadvertent consequences, a careful case-by-case analysis on product level must be performed for any substitution.

By 2050, 38% of packaging can be reduced, with reuse models offering the greatest potential impact



*Note: The Current Actions reduction includes the ban and reduction of single use plastics applications as per the Single Use Plastics Directive and the pro-rated

In 2030, increases in separate collection, sorting efficiency and recycling yields lead to an effective recycling rate of 44% for plastic packaging

In the Circularity Scenario, mechanical recycling of packaging waste can grow from 2.9 Mt of recyclates in 2020 to 5.1 Mt in 2030, even with declining waste volumes driven by reduction and substitution

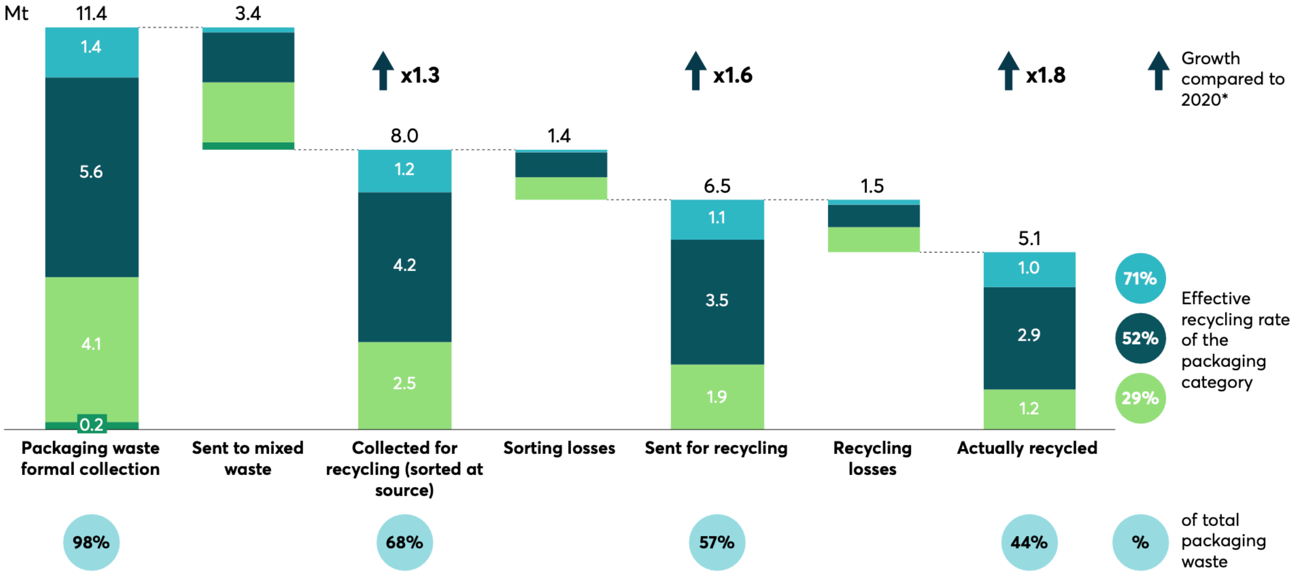
Design for recycling results in shift from MLMM to rigid (25%) and flexible (40%) mono-material packaging

Separate collection rates are assumed to increase to 90% for bottles, 75% for rigids, and 60% for flexibles as result of the PPWD

Improvements in sorting efficiencies are due to technological, behavioural and design improvements, converging to best practice practices in Europe

Recycling yields increase as a result of technological improvements and higher quality input streams, leading to a growth of recyclate output by 180% compared to 2020

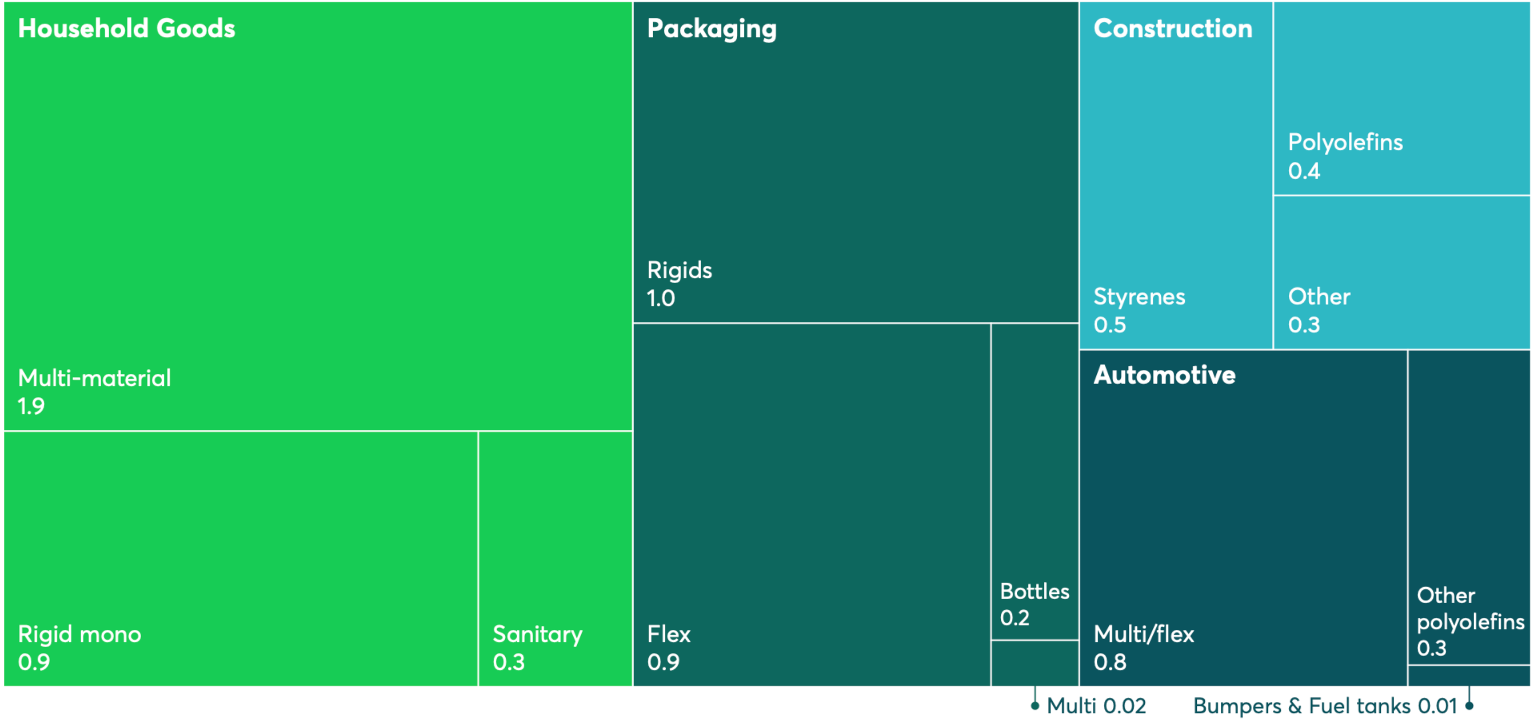
Bottles
Rigids
Flex
Multi-layer/ Multi-material



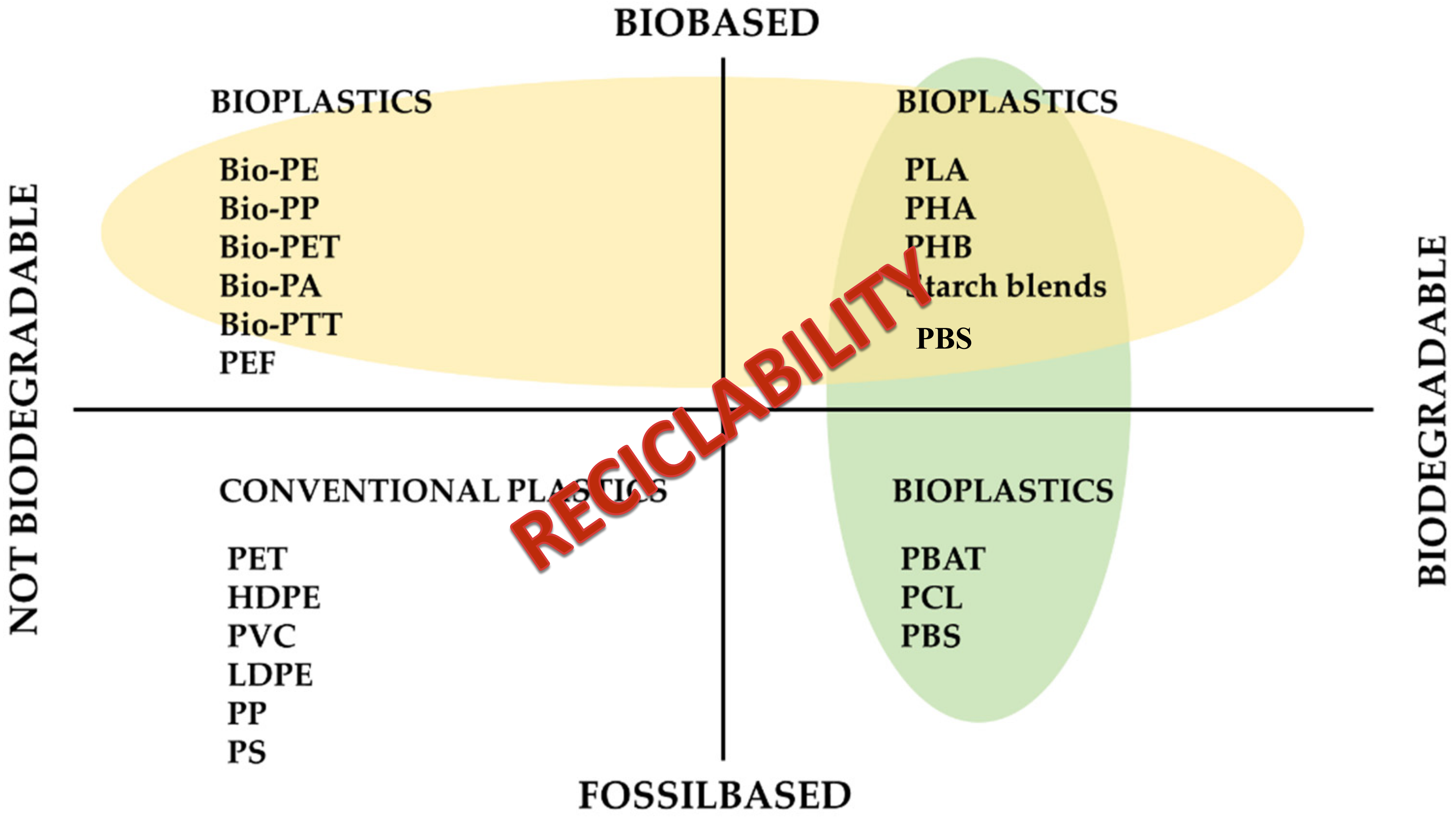
*Note: To illustrate the mechanical recycling output growth in the Circularity Scenario more effectively, the output values are compared to 2020 numbers as Reduction & Substitution reduce overall plastic waste volumes, making a direct comparison to the Current Actions Scenario difficult.
Source: "ReShaping Plastics" model

In 2050, 7.5 Mt of plastic could be chemically recycled across under the Circularity Scenario

Volumes of chemical recycling per plastic sub-system and category in 2050 (Mt)

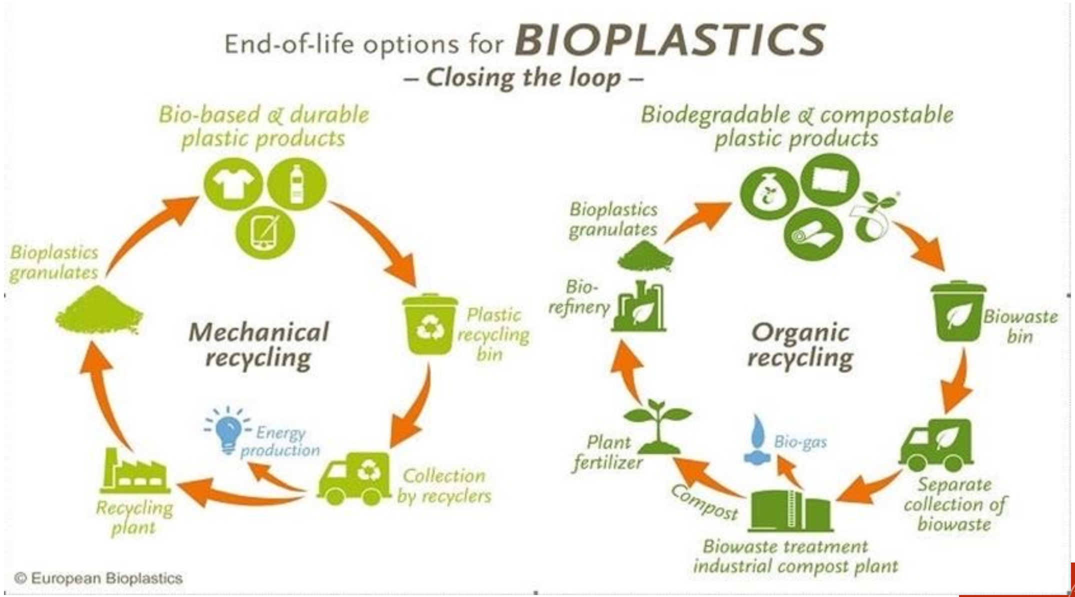


Source: "ReShaping Plastics" model

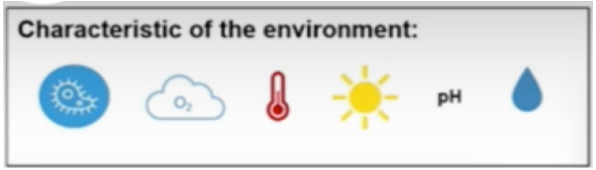

BIOBASED
BIOPLASTICS
Bio-PE
Bio-PP
Bio-PET
Bio-PA
Bio-PTT
PEF
BIOPLASTICS
PLA
PHA
PHB
Starch blends
PBS
NOT BIODEGRADABLE
BIODEGRADABLE
RECICLABILITY
CONVENTIONAL PLASTICS
PET
HDPE
PVC
LDPE
PP
PS
BIOPLASTICS
PBAT
PCL
PBS
FOSSILBASED

Do biodegradable plastics contaminate mechanical recycling streams?

There is no negative impact of possibly remaining impurities of compostable plastics on existing recycling streams. Existing sorting technologies, such as density separation and NIR (near-infrared) sorting, can efficiently separate and sort different kinds of polymers, including compostable plastics. Any remaining contamination will be insignificant and the potential impact negligible after sorting.

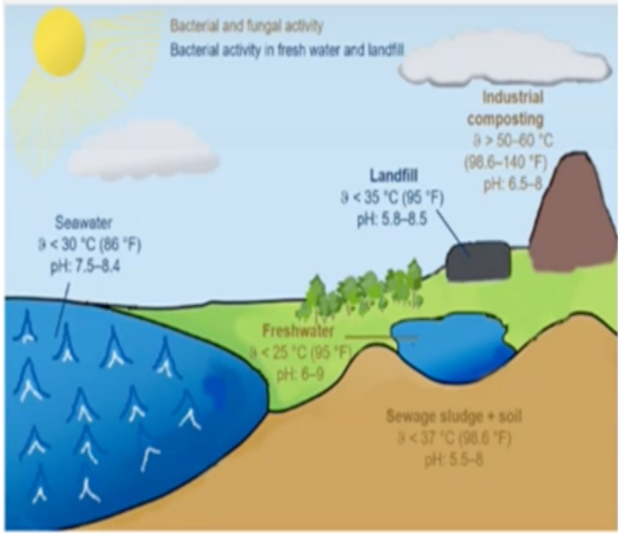


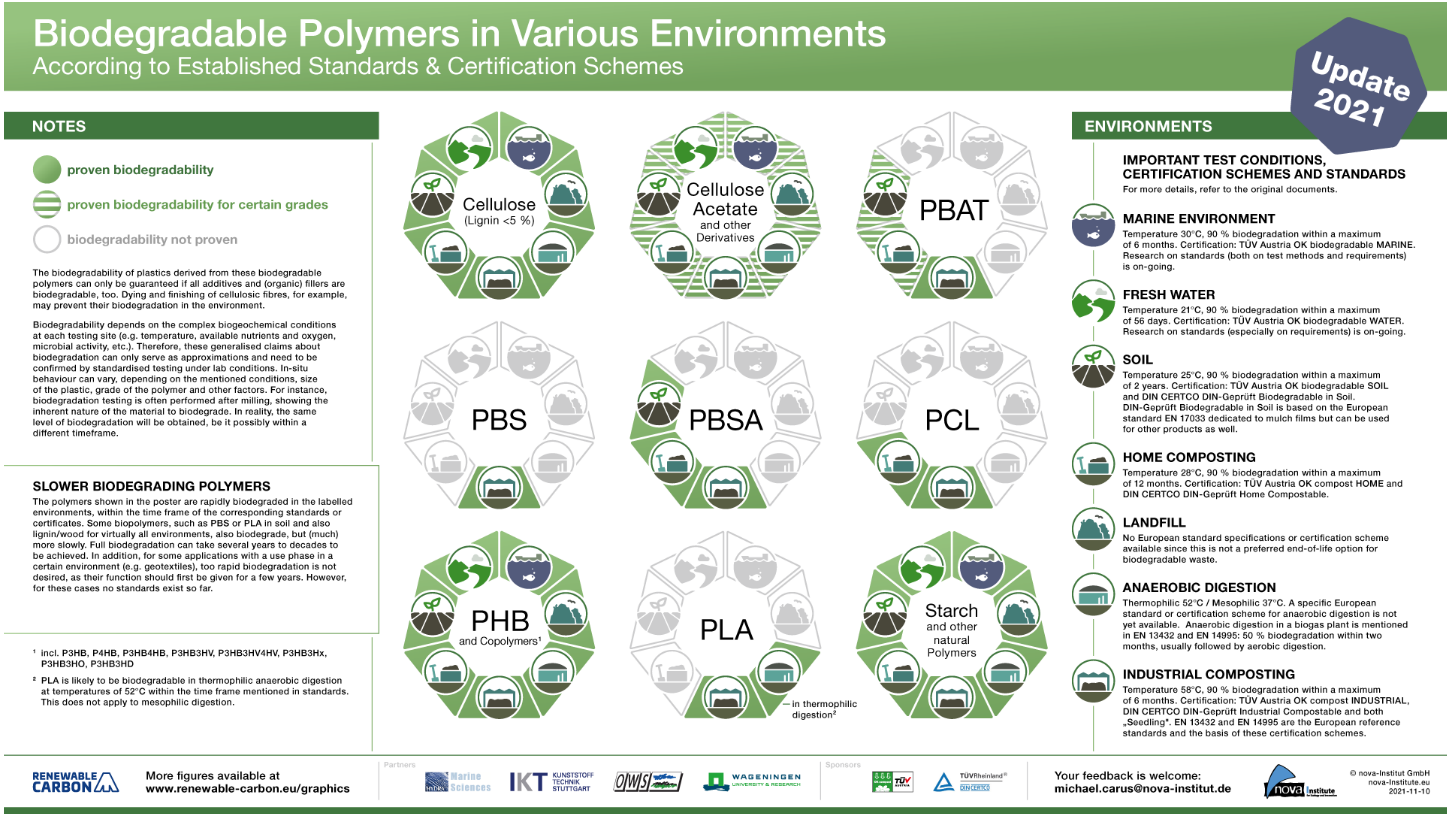
Biodegradability seen as a system property:



AGRESSIVITY OF BIODEGRADATION (+ to −)

INDUSTRIAL COMPOSTING	High temperature, fungi, bacteria, actinomycetes
HOME COMPOSTING	Ambient temperature, fungi, bacteria, actinomycetes
SOIL	Ambient temperature, fungi, bacteria, actinomycetes
FRESH WATER	Ambient temperature, Bacteria only
MARINE WATER	Ambient temperature, Diluted bacteria only
LANDFILL	Ambient temperature, Bacteria only





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