# PACKALL

PackAlliance:
European alliance for innovation training
& collaboration towards future packaging

## Linking Academy to Industry.

**Training program: modules**

- **Eco-design & novel manufacturing processing**
  - New materials and biomaterials
  - Citizen and Consumer Engagement
  - Residue management and valorisation

Co-funded by the Erasmus+ Programme of the European Union

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# MODULE 2: ECODESIGN

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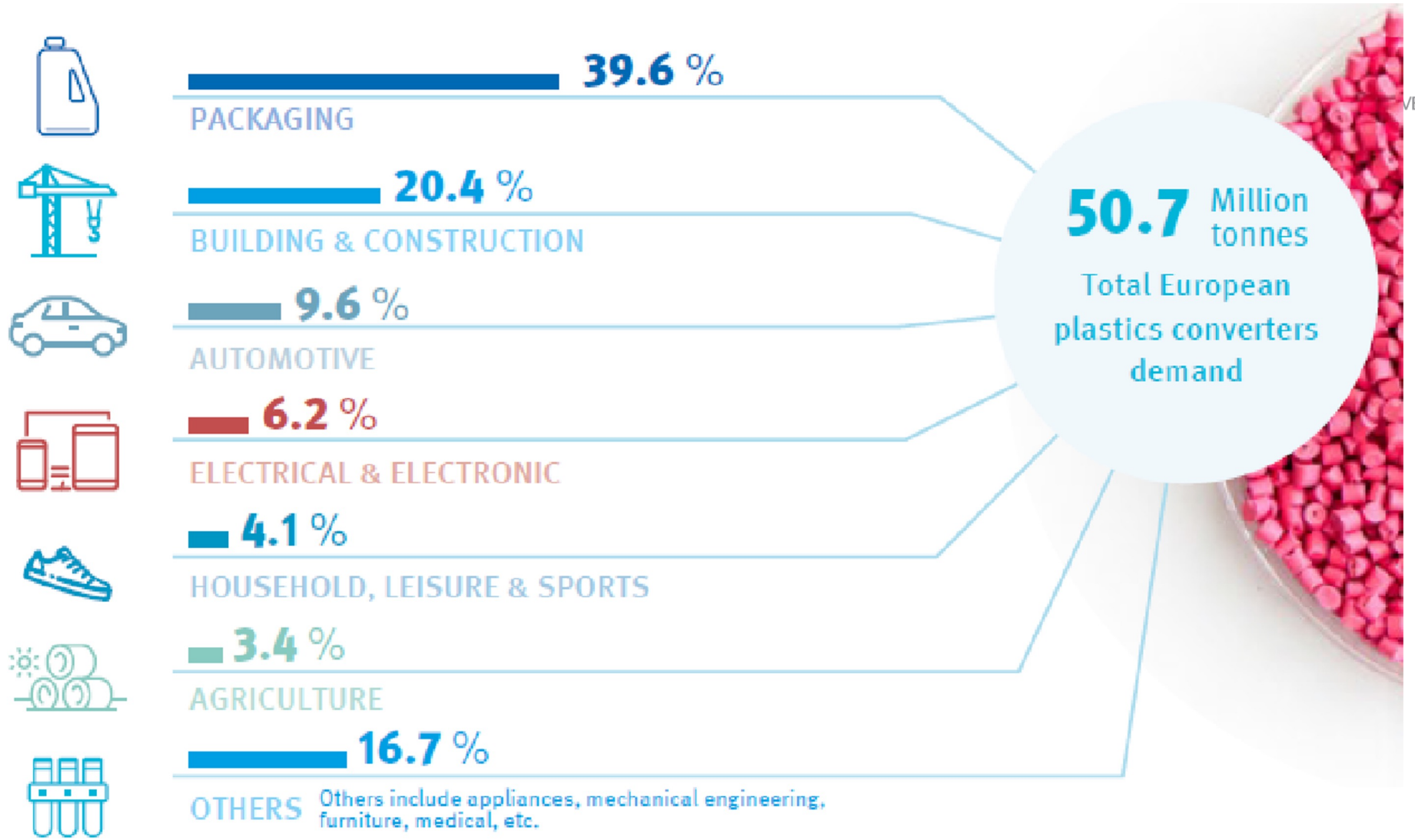
VERSITÀ DEGLI STUDI
DI SALERNO




*Fonts: Plastics Europe*

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**11.3 %**
Food packaging (dairy, fishery), building insulation, electrical & electronic equipment, inner liner for fridges, eyeglasses frames, etc.

**19.4 %**
Food packaging, sweet and snack wrappers, hinged caps, microwave containers, pipes, automotive parts, bank notes, etc.

**6.2 %**

**7.5 %**
Hub caps (ABS); optical fibers (PBT); eyeglasses lenses, roofing sheets (PC); touch screens (PMMA); cable coating in telecommunications (PTFE); and many others in aerospace, medical implants, surgical devices, membranes, valves & seals, protective coatings, etc.

**7.9 %**
Bottles for water, soft drinks, juices, cleaners, etc.

**17.4 %**
Reusable bags, trays and containers, agricultural film, food packaging film, etc.

**7.9 %**
Building insulation, pillows a and mattresses, insulating foams for fridges, etc.

**12.4 %**
Toys, milk bottles, shampoo bottles, pipes, houseware, etc.

**10 %**
Window frames, profiles, floor and wall covering, pipes, cable insulation, garden hoses, inflatable pools, etc.

*Fonts: Plastics Europe*

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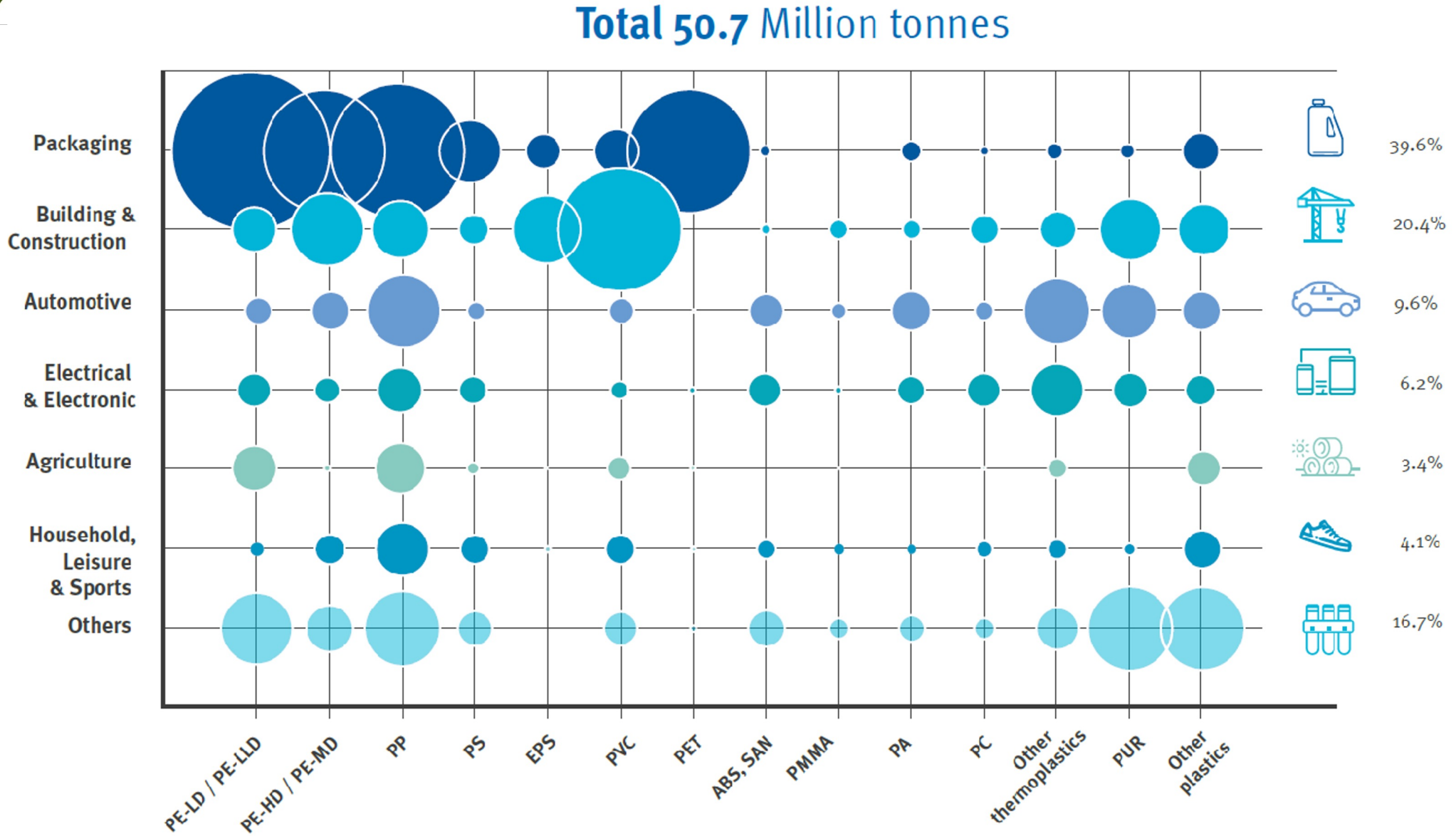


*Fonts: Plastics Europe*

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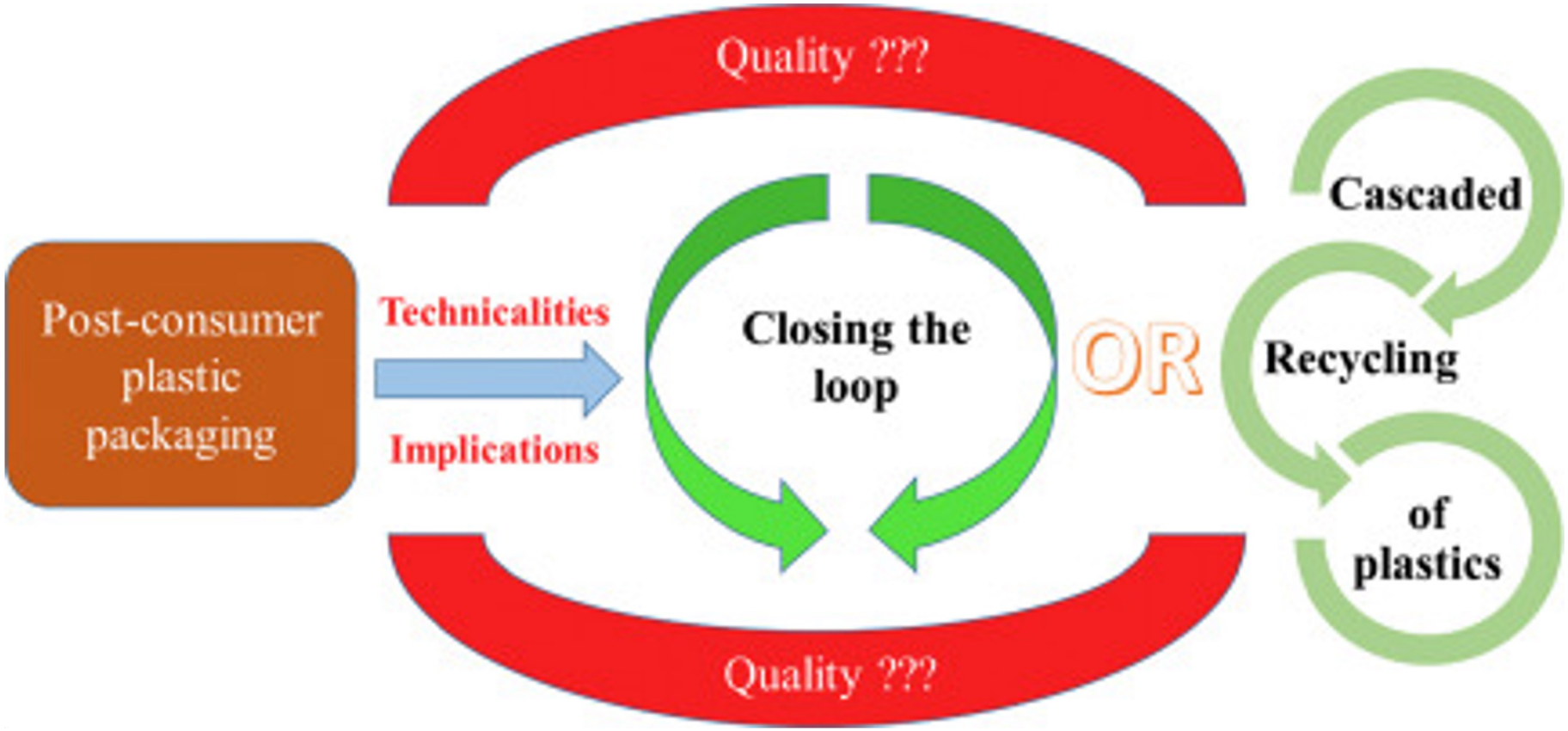
# *Maximize* material lifetime




Fonte: Science of the Total Environment 630 (2018) 1394–1400

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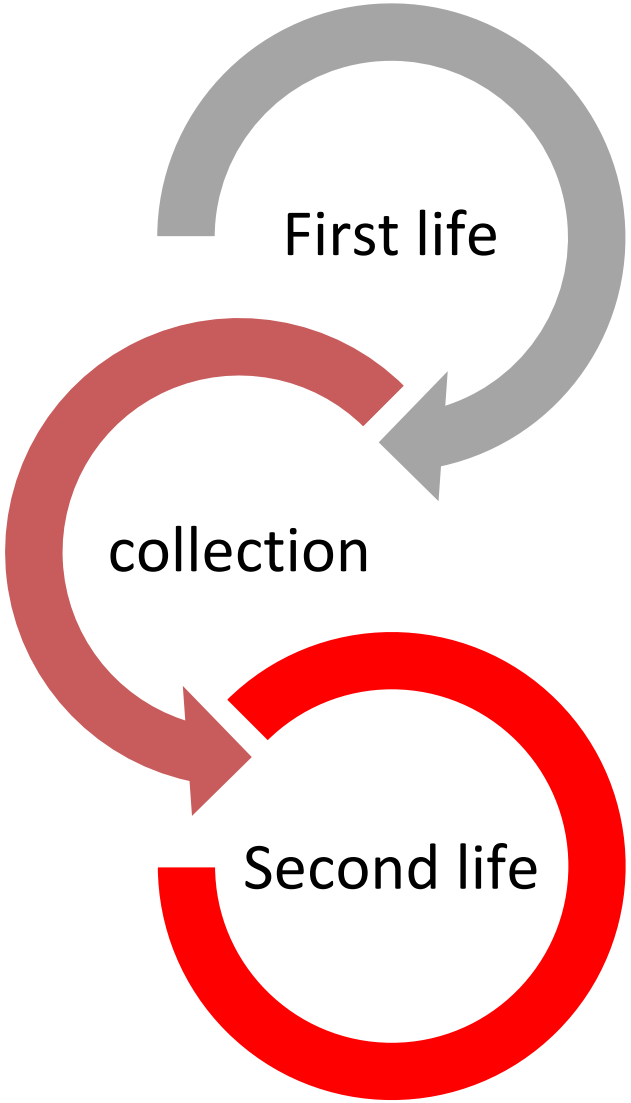
# *Maximize* material lifetime




Plastic is a long lasting material

its intrinsic property that makes it not biodegradable will help in the management of life time

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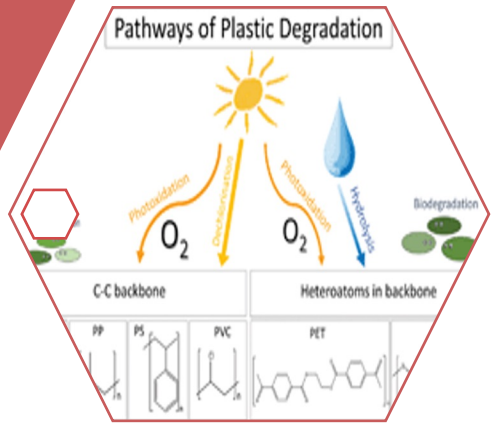
# *Maximize* material lifetime

First life


Material initial composition

External condition




Processing condition

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Polymer can degrade by exposure to:

| | | |
|---|---|---|
| High temperature | → | Thermal degradation |
| Shear action | → | Mechanical degradation |
| Oxygen, ozone and chemicals | → | Chemical degradation |
| Electromagnetic | → | Light induced degradation |
| Ultrasonic radiation | | |
| Moisture | → | Hydrolysis |

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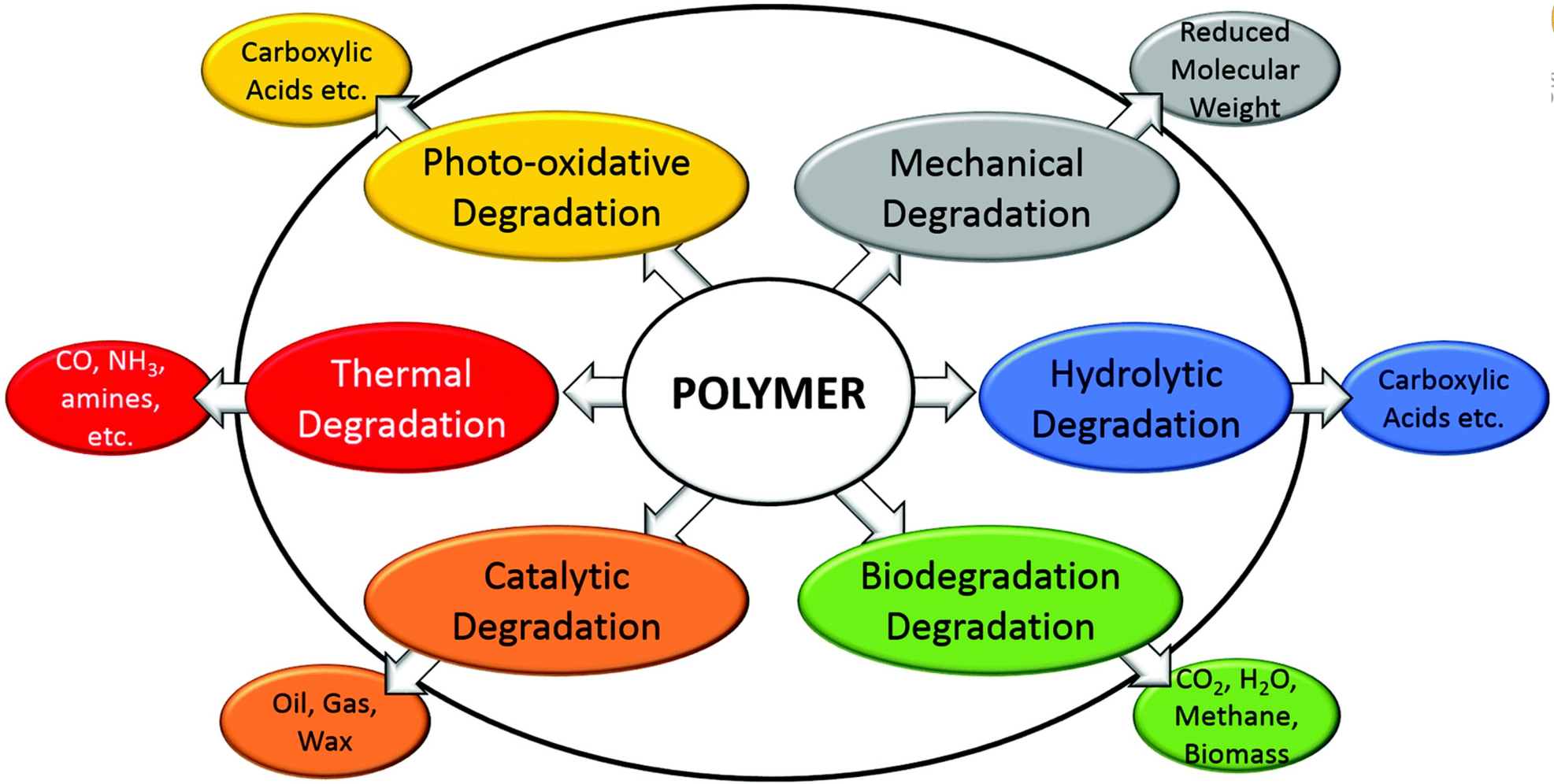


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# DEGRADATION DURING PROCESSING

## Thermo-mechanical degradation

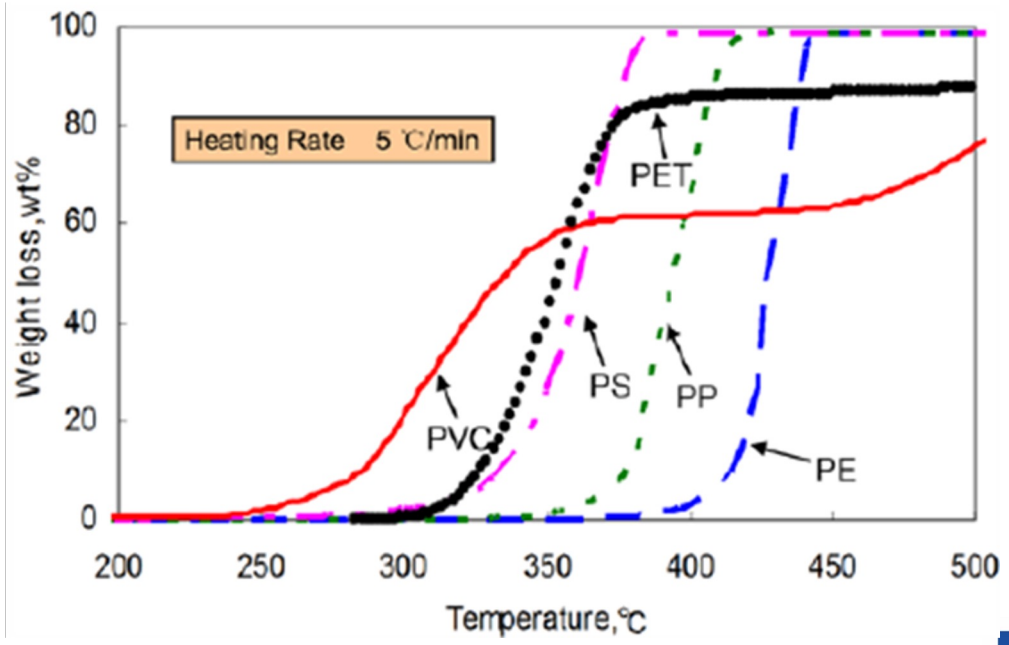
Molten polymers are non-Newtonian fluids with high viscosities and the interaction between their thermal and mechanical degradation can be complex. At low temperatures the polymer-melt is more viscous and more prone to mechanical degradation via shear stress.

At higher temperatures the viscosity is reduced but thermal degradation is increased. Friction at points of high sheer can also cause localized heating leading to additional thermal degradation.

Mechanical degradation can be reduced by the addition of lubricants, also referred to as processing aids or flow aids. These can reduce friction against the processing machinery but also between polymer chains, resulting in a decrease in melt-viscosity. Common agents are high molecular weight waxes (paraffin wax, wax esters, etc) or metal stearates (i.e.zinc stearate)

## Thermal degradation

Heating polymers to a sufficiently high temperature can cause damaging chemical changes, even in the absence of oxygen. This usually starts with chain scission, generating free radicals, which primarily engage in disproportionation and crosslinking. PVC is the most thermally sensitive common polymer, with major degradation occurring from ~250°C onwards, other polymers degrade at higher temperatures.

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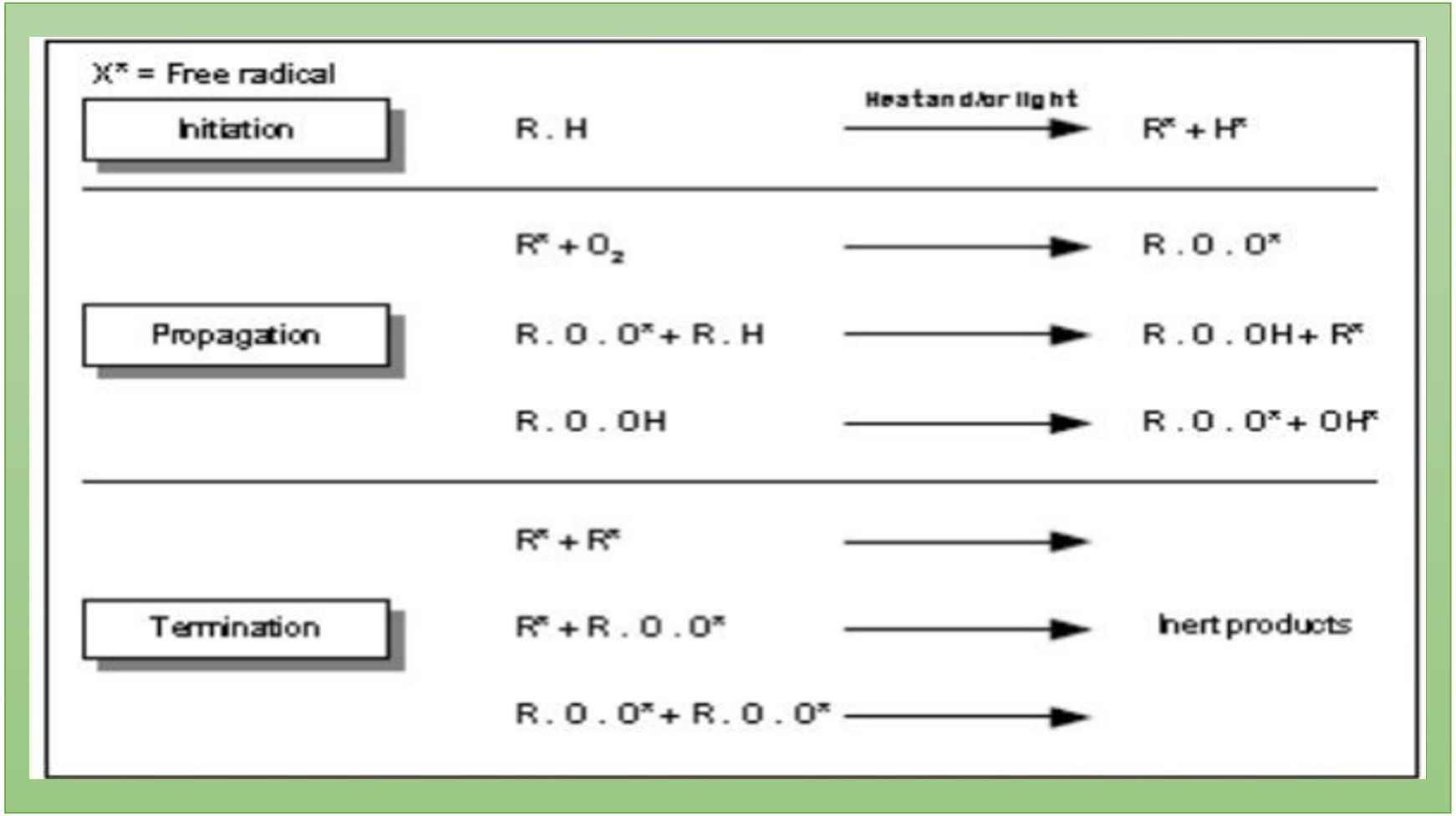
# DEGRADATION DURING PROCESSING

## MECHANISM

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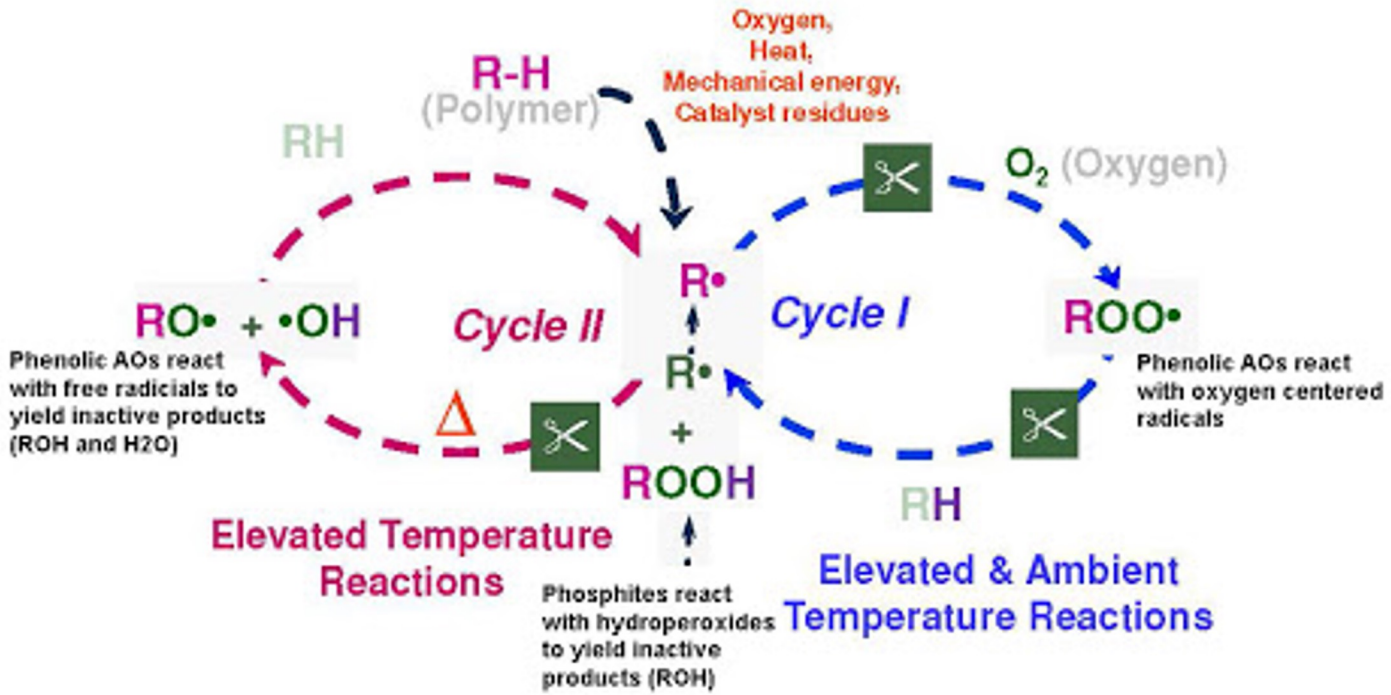
## Thermal oxidation

Although oxygen levels inside processing equipment is usually low it cannot be fully excluded, and thermal-oxidation will usually take place more readily than degradation which is exclusively thermal (i.e. without air). Reactions follow the general autoxidation mechanism, leading to the formation of organic peroxides and carbonyls. Such processes may be inhibited by the addition of antioxidants.

The use of antioxidant help polymer protection against thermal oxidation, acting as radical scavenger to chain breakage propagation




*Everspring Middle East 2012*

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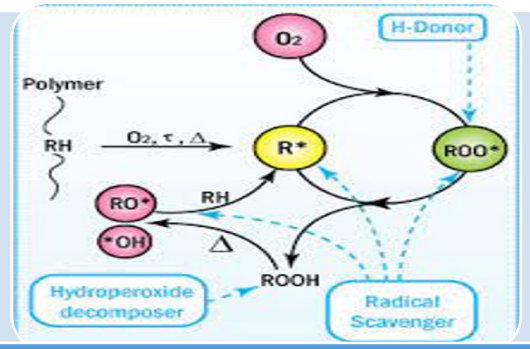
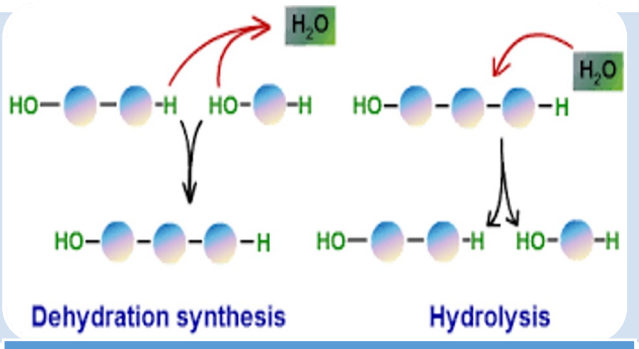
# DEGRADATION IN THE ENVIRONMENT




## Photo-oxidation

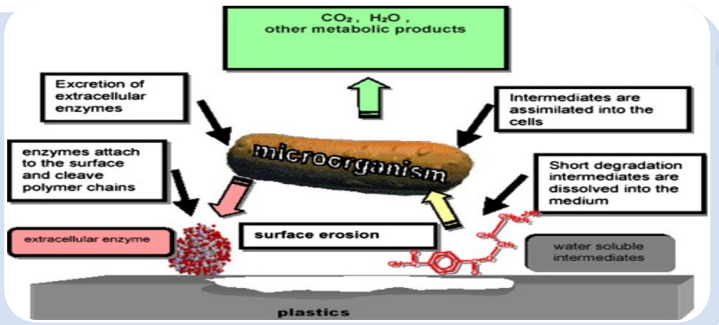
Photo-oxidation is the combined action of UV-light and oxygen and is the most significant factor in the weathering of plastics. Although many polymers don't absorb UV-light, they often contain impurities which do, such as hydroperoxide and carbonyl groups introduced during thermal processing. These act as photo initiators to give complex free radical chain-reactions where the mechanisms of autoxidation and photo degradation combine. Photo-oxidation can be held back by light stabilizers such as HALS

Fonte immagine: https://adhesives.specialchem.com/selection-guide/antioxidants-for-adhesives




## Hydrolysis

Polymers with an all-carbon backbone, such as polyolefins, are usually resistant to hydrolysis. Condensation polymers like polyesters,[ polyamides, polyurethanes and polycarbonates can be degraded by hydrolysis of their carbonyl groups, to give lower molecular weight molecules. Such reactions are exceedingly slow at ambient temperatures, however they remain a significant source of degradation for these materials, particularly in the marine environment. Swelling caused by the absorption of minute amounts of water can also cause environmental stress cracking, which accelerates degradation.




## Biological degradation

The major appeal of biodegradation is that, the polymer will be completely consumed in the environment without the need for complex waste management and that the products of this will be non-toxic. Most common plastics are considered non-biodegradable. As polymers are ordinarily too large to be absorbed by microbes biodegradation initially relies on secreted extracellular enzymes to reduce the polymers to manageable chain-lengths. This requires that the polymers bare functional groups that the enzymes are able to 'recognise', such as ester or amide groups. Long-chain polymers with all-carbon backbones such as polyolefins, polystyrene and PVC will not degrade by biological action alone[30] and must first be oxidized to create chemical groups which the enzymes can attack.

Fonte imagine: Biotechnology Advances Volume 26, Issue 3, May–June 2008, Pages 246-265

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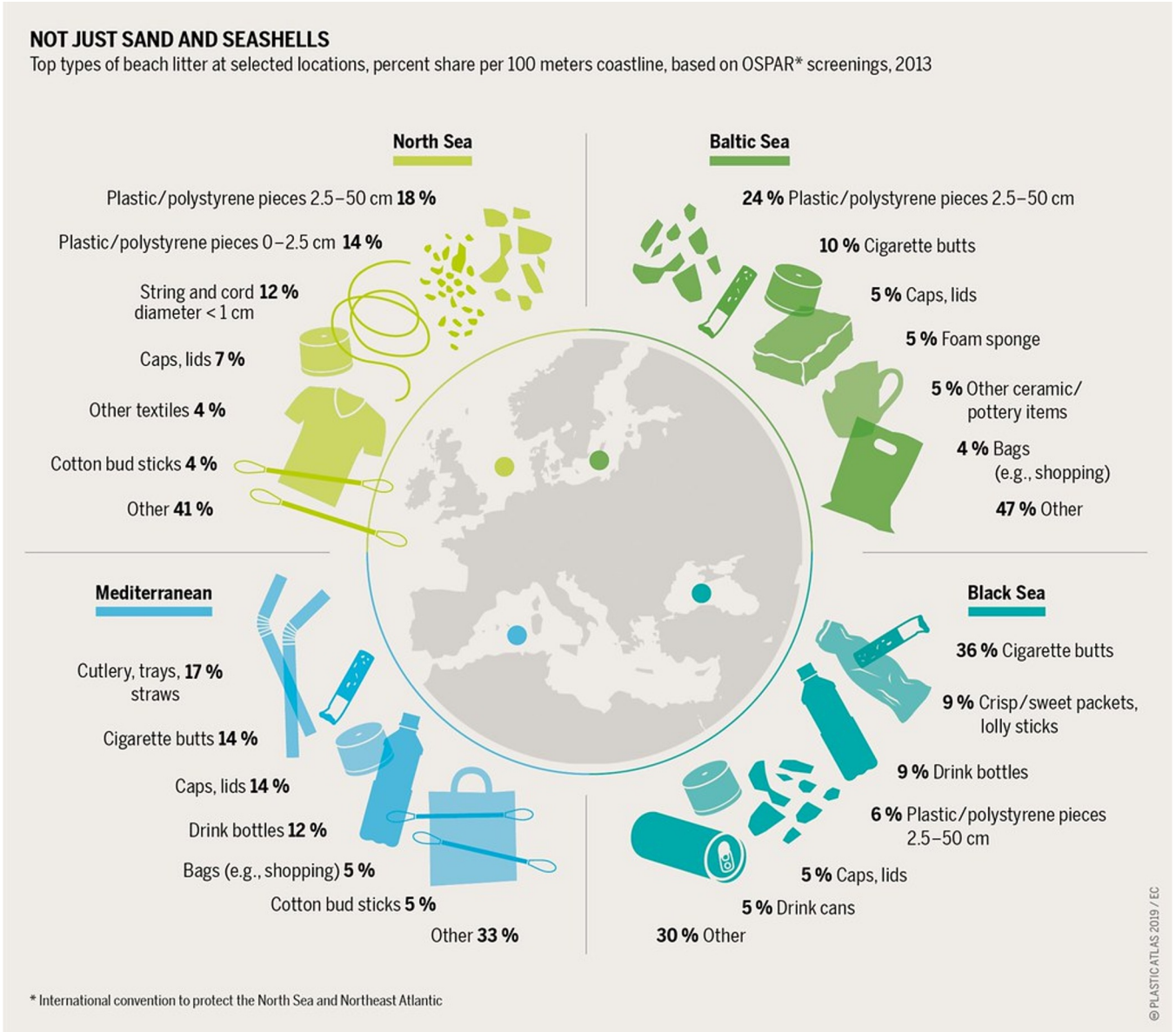
# What happens if plastic stays in the environment after use?

Marin litter

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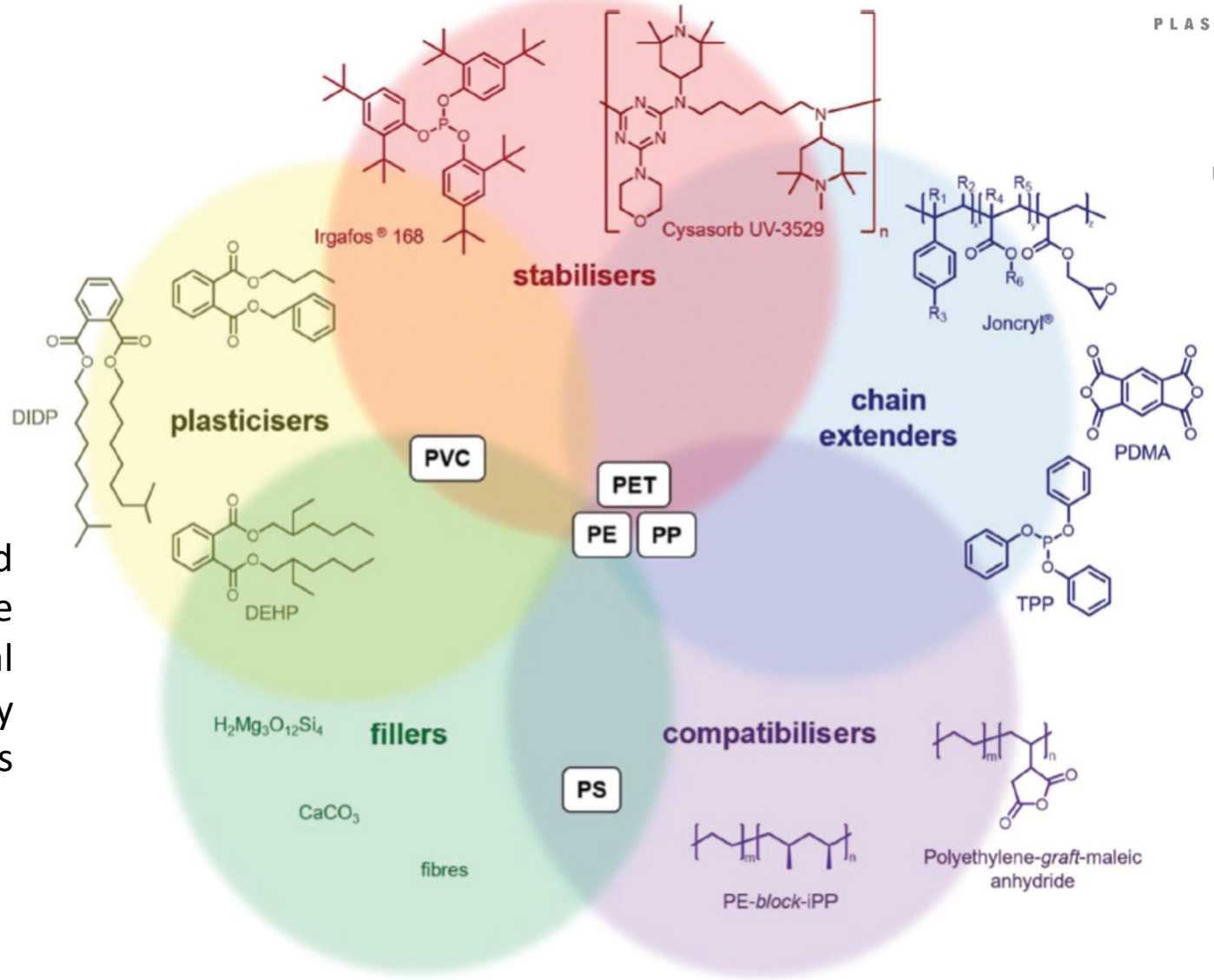
# Second life

Polymeric structure is modified following recycling operations, due to thermal and mechanical degradation processes that may reduce considerably their properties and limit their fields of use.




Common polymer additives used to improve polymer recyclates.

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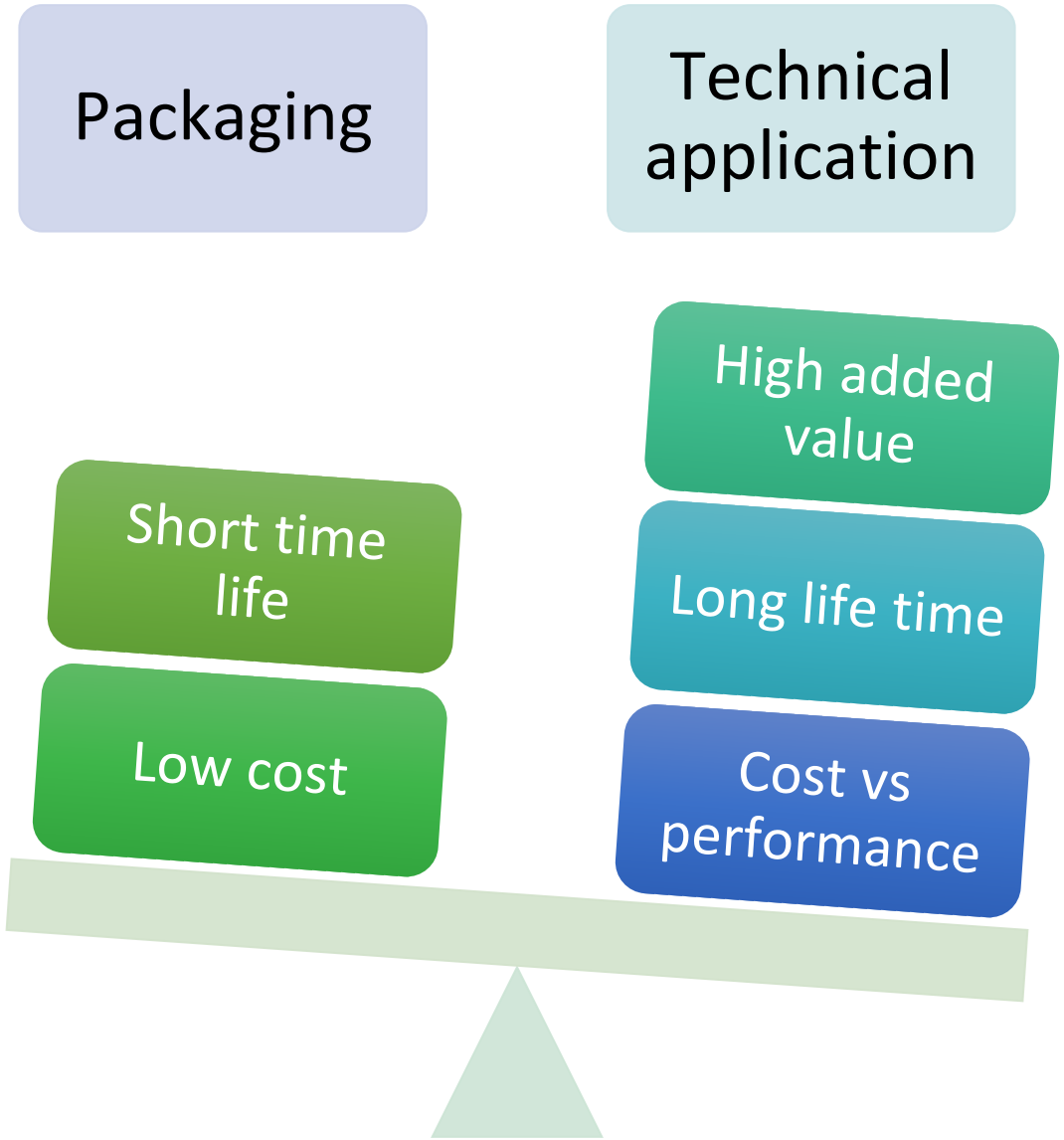


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AGH

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