IPCP Webinar Series: POPs in plastic and monitoring approaches

Part I: Understanding POPs in plastics; 24/25 April 2023

Short Introduction to Polymers, Plastics, Additives and other Plastic-related Chemicals

Dr. Roland Weber[1,2] ; Dr. Zhanyun Wang[1,3]

[1]International Panel on Chemical Pollution

[2]POPs Environmental Consulting, 73527 Schwäbisch Gmünd, Germany

[3]EMPA Swiss Federal Laboratories for Materials Science and Technology, Switzerland

IPCP International Panel on Chemical Pollution

UN environment programme

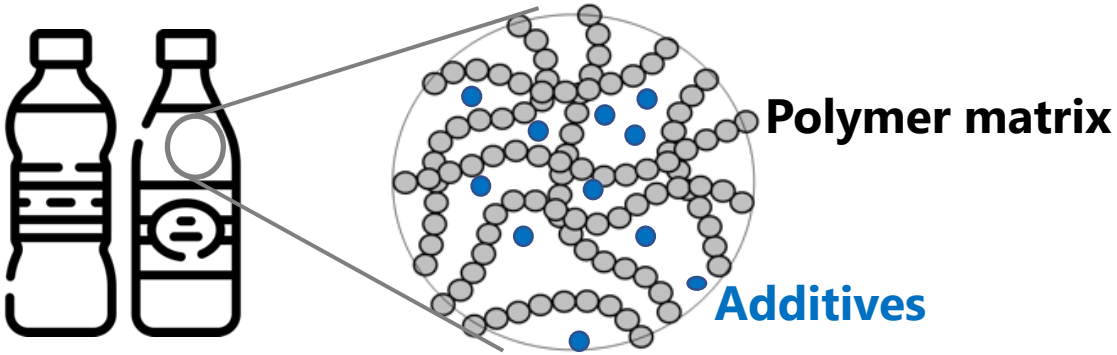
gef

Content

- What are plastics
- Different grouping of plastics
- Plastics and Their Major Applications
- Different types of plastic additives and their functions

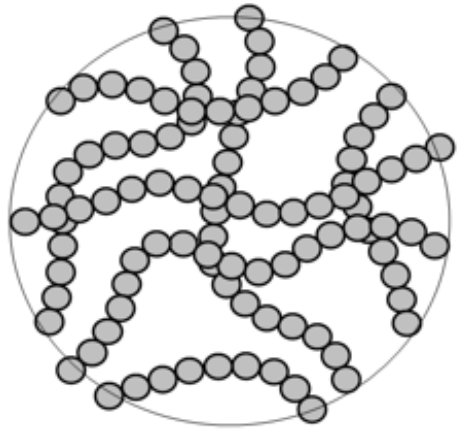
What are Plastics?

- Greek: *plastikos* = capable of being shaped or moulded
- **Plastics vs. polymers**
  - **A polymer** is a substance or material consisting of very large molecules called macromolecules, composed of many repeating sub-units (vinyl chloride - polyvinyl chloride).
  - **Plastics** are composed of **organic polymers** and **additives (e.g. plasticisers)**



  - All plastics are polymers, but not all polymers are plastics.

Different Terminologies Exist for Plastics



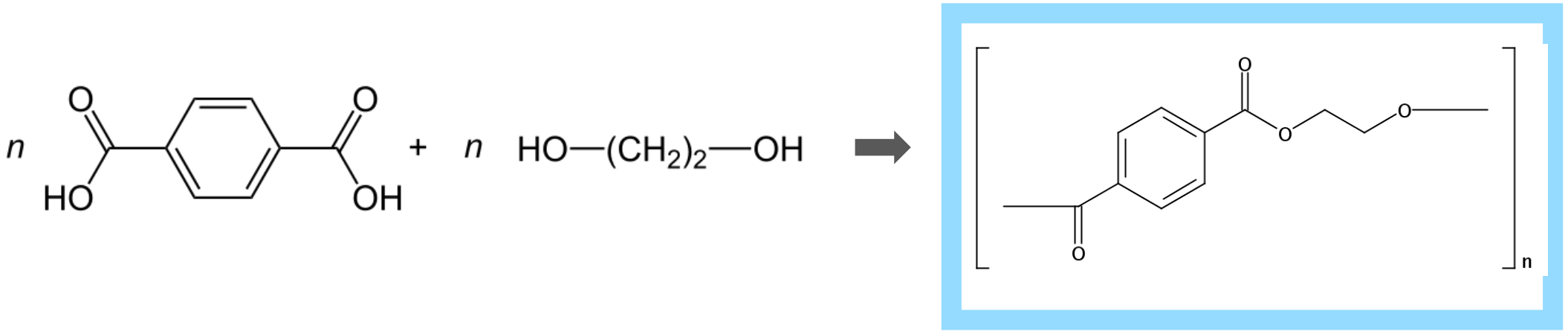
Plastics are generally named after the polymer matrix.

- **Named after their monomers**, e.g.,
  - poly*ethylene* (PE), poly*styrene* (PS), poly*vinyl chloride* (PVC)

- **Named after characteristic groups in their repeating units**, e.g.,
  - polyamides (PA) → amide groups, R**–NHC(O)–**R' (e.g., Nylon)
  - polyesters (PES) → ester groups, R**–C(O)O–**R'
  - polyurethanes (PUR / PU) → urethane groups, R**–NH–C(O)–O–**R'

- **IUPAC names after their full chemical structure**, e.g.,
  - $–[O\text{-}CH_2]_n–$ → poly(oxymethylene)

Thus, one plastic may have many names

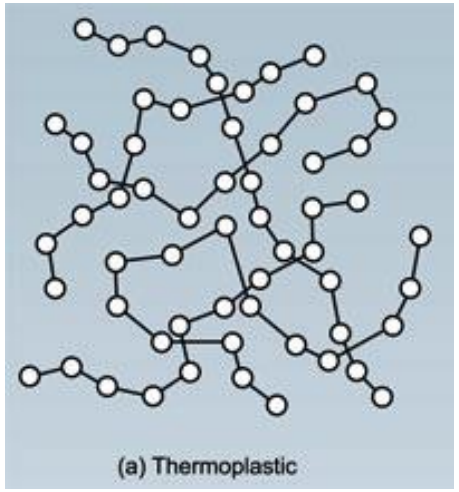


- **Named after their monomers**
  - poly(ethylene glycol terephthalate) → PET, PETP (plastics literature), PETE (recycling)
- **Named after characteristic groups in their repeating units**
  - Polyester → PES (fiber literature)
- **IUPAC names / full chemical structure**
  - poly(oxy-1,2-ethanediyloxycarbonyl-1,4-phenylenecarbonyl)
  - poly(oxyethyleneoxyterephthaloyl)

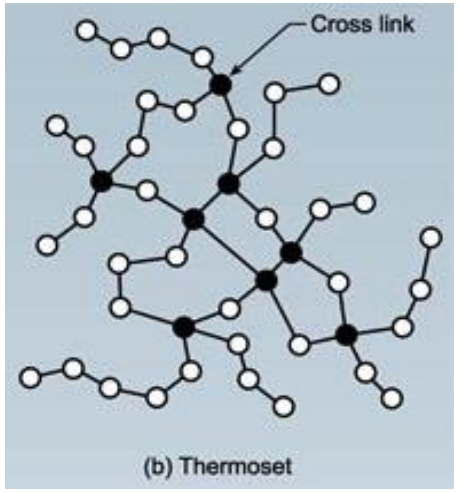
Different Grouping of Plastics (1) - according to hardening processes

According to their hardening processes:

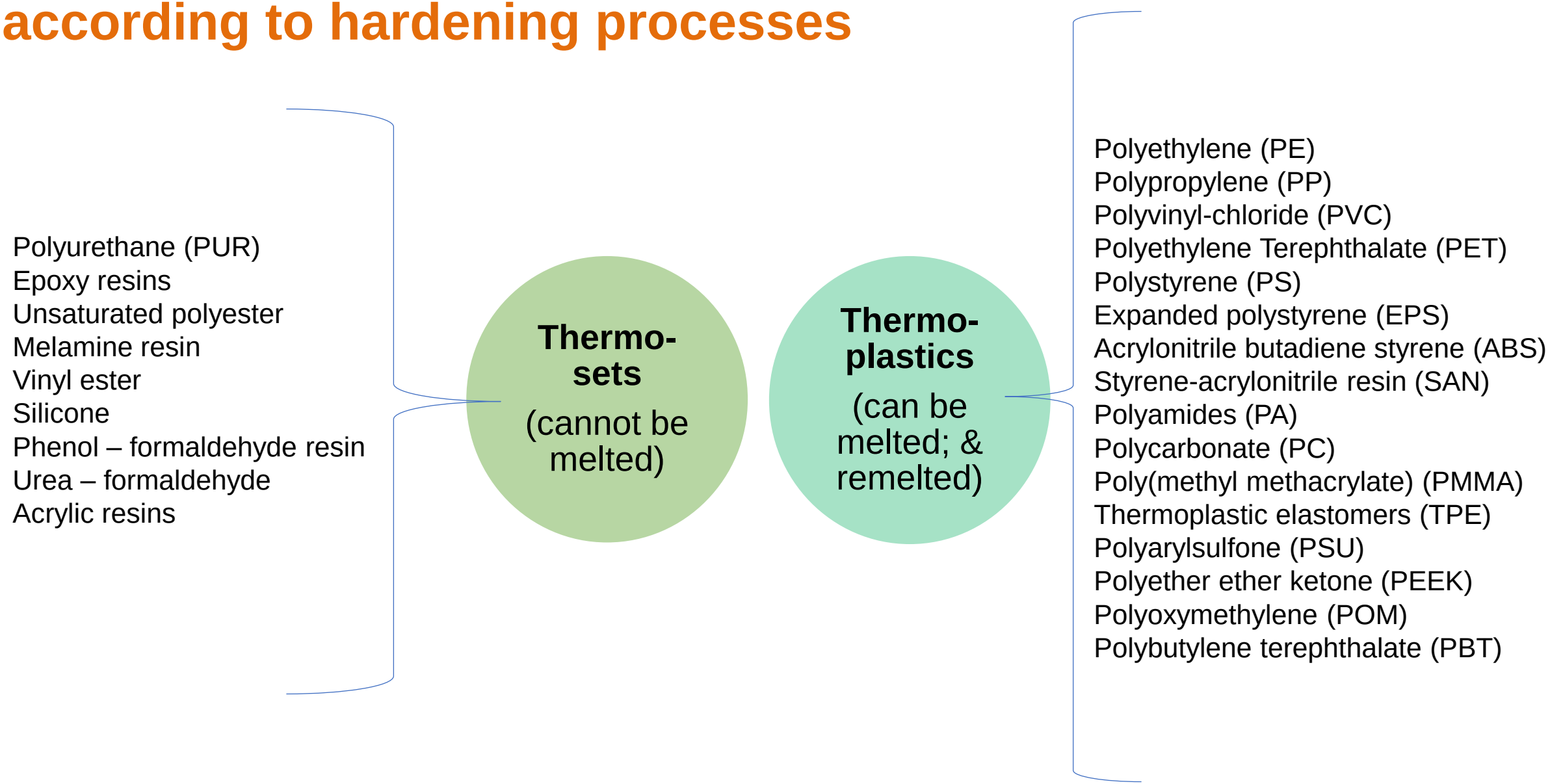
- **Thermoplastics:** harden through simple cooling of a polymer melt (a physical process) and soften while being heated, e.g.,
  - PE, PP, PVC, ABS, etc.



- **Thermosets:** harden through **chemical cross-linking reactions between polymer molecules;** when heated, they do not soften but decompose chemically at higher temperatures, e.g.,
  - **polyurethane, epoxy**, unsaturated polyesters, amino, allylic resins



Different Grouping of Plastics (1) - according to hardening processes



Different Grouping of Plastics (2) – According to their cost and performance

According to their **cost and performance:**

- **Commodity** (or standard/bulk) plastics: high production at low cost, e.g.,
  - HDPE, LDPE, PP, PVC, PS, EPS, PET

- **Engineering** (or technical) plastics: plastics with improved mechanical properties and dimensional stability compared to commodity plastics, e.g.,
  - HIPS, PA, PC, ABS, PPC-ABS, PO-PS, POM-PUR, PBT, PET, POM, PMMA, SAN, etc.

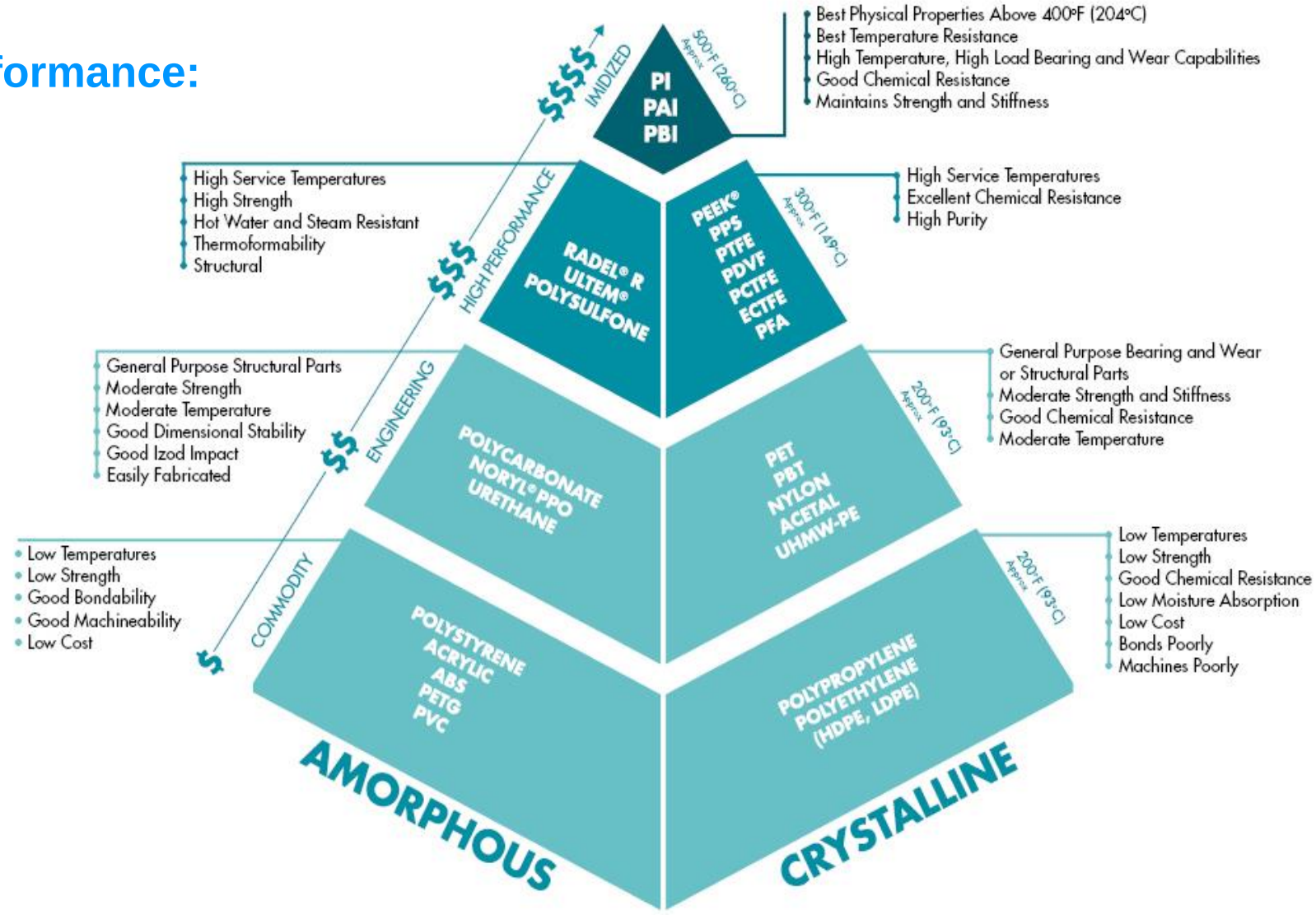
- **High-performance** (or specialty) plastics: engineering plastics with even more improved mechanical properties, e.g.,
  - liquid crystal polymers (LCPs), fluoropolymers (e.g., PTFE, PVDF), polyetheretherketone (PEEK).

• ABS = acrylonitrile butadiene styrene; EPS = expanded polystyrene; HDPE = high-density polyethylene; HIPS = high impact polystyrene; LDPE = low-density polyethylene; LLDPE = linear low-density polyethylene; PA = polyamide; PBT = polybutylene terephthalate; PC = polycarbonate; PET = polyethylene terephthalate; POM = polyoxymethylene; PMMA = poly(methyl methacrylate); PP = polypropylene; PPO = poly(p-phenylene oxide); PS = polystyrene; PTFE = polytetrafluoroethylene; PUR = polyurethane; PVC = polyvinyl chloride; PVDF = polyvinylidene fluoride; SAN = styrene-acrylonitrile resin; VLDPE = very-low-density polyethylene;

Different Grouping of Plastics (2) – According to cost and performance

According to their **cost and performance:**

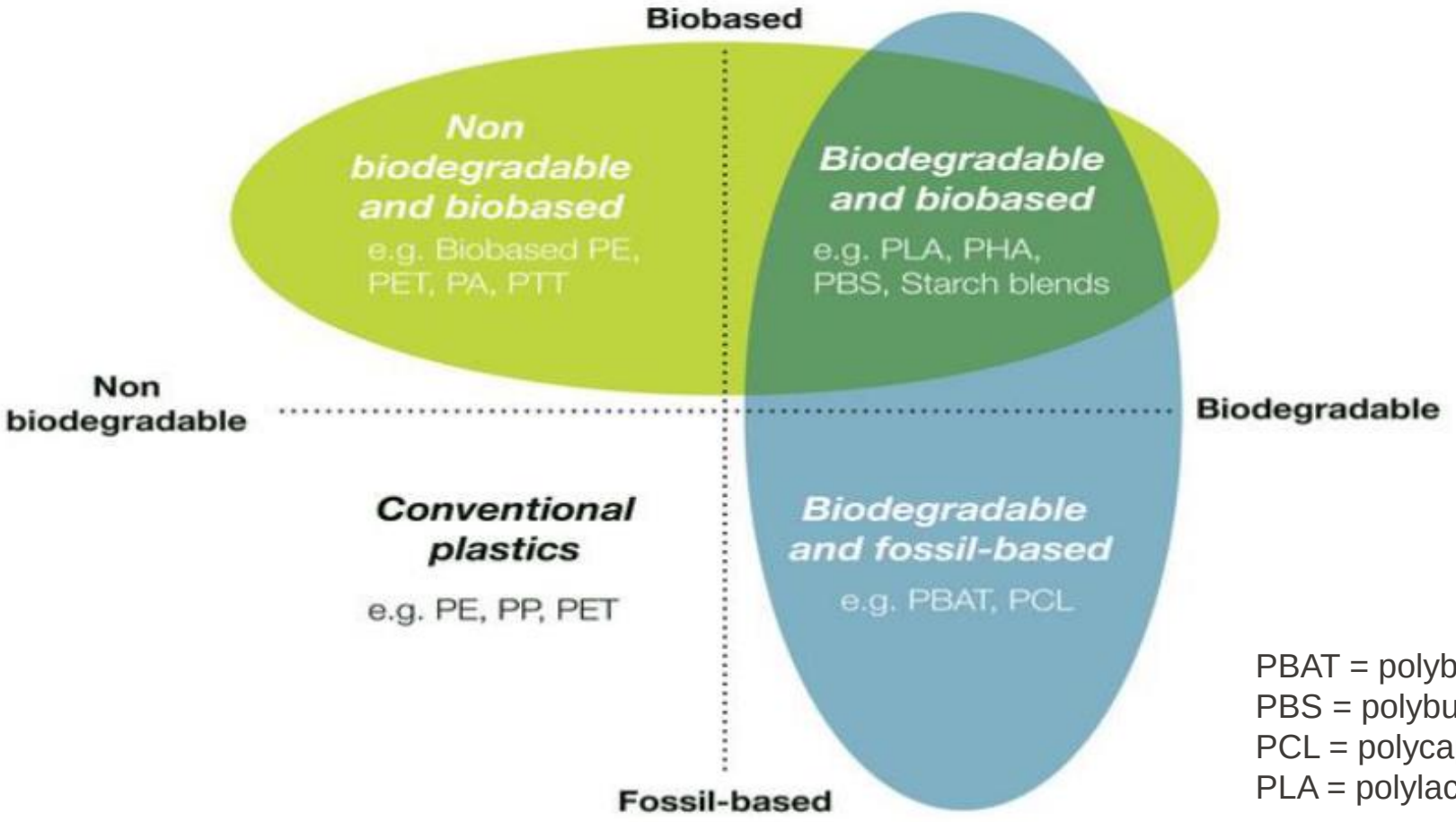
- Every application has unique material-characteristic requirements for temperature, strength, cost, etc.
- **IMPORTANT:** The commodity plastics, particularly PE and PP, are low-cost plastics, and are dominant in production and waste generation.



Source: https://divplast.com/plastics-material-selection/

Different Grouping of Plastics (3) – According to origin of feedstock and biodegradability

- According to the **origin of feedstock:** **fossil- vs. bio-based plastics**
- According to the **biodegradability:** **biodegradable vs. non-biodegradable plastics**

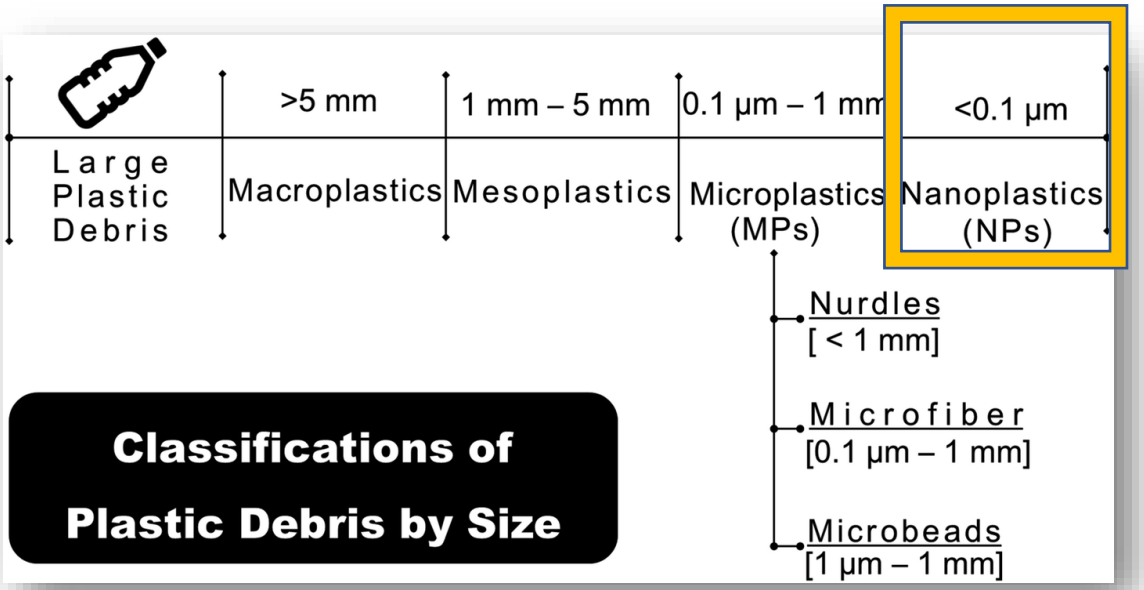


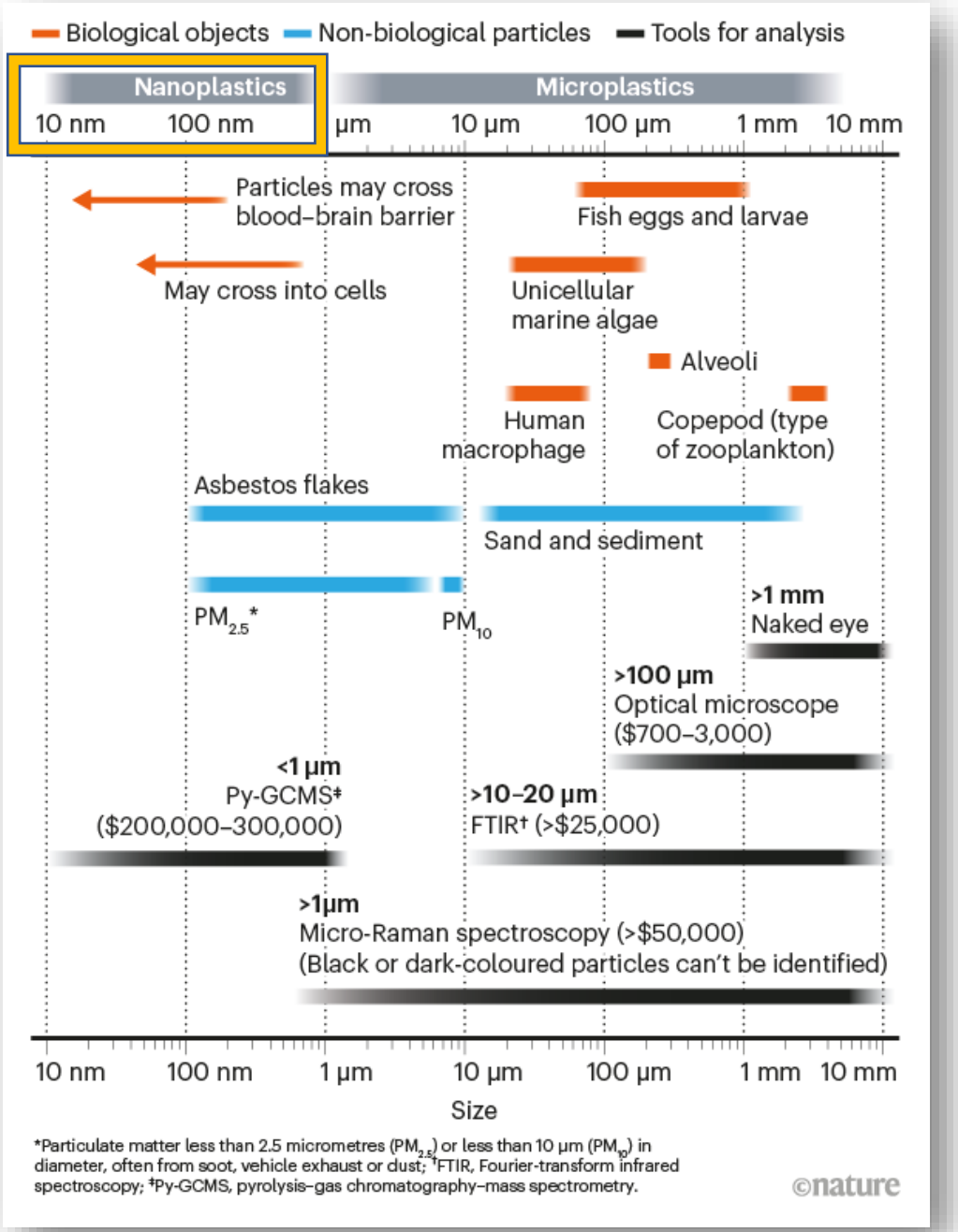
PBAT = polybutylene adipate terephthalate;
PBS = polybutylene succinate;
PCL = polycaprolactone; PHA = polyhydroxyalkanoate;
PLA = polylactic acid; PTT = polytrimethylene terephthalate;

Different Grouping of Plastics (4) – According to Size

According to their particle **size: macro – micro - nano**

→ **No commonly agreed definition on micro- and nano-plastics yet**





https://pubs.rsc.org/de-ch/content/articlelanding/2022/em/d1em00443c/unauth

Different Grouping of Plastics (5) - According to use pattern

According to their **use patterns:**

- **Single-use** *vs.* **non-single-use plastics**

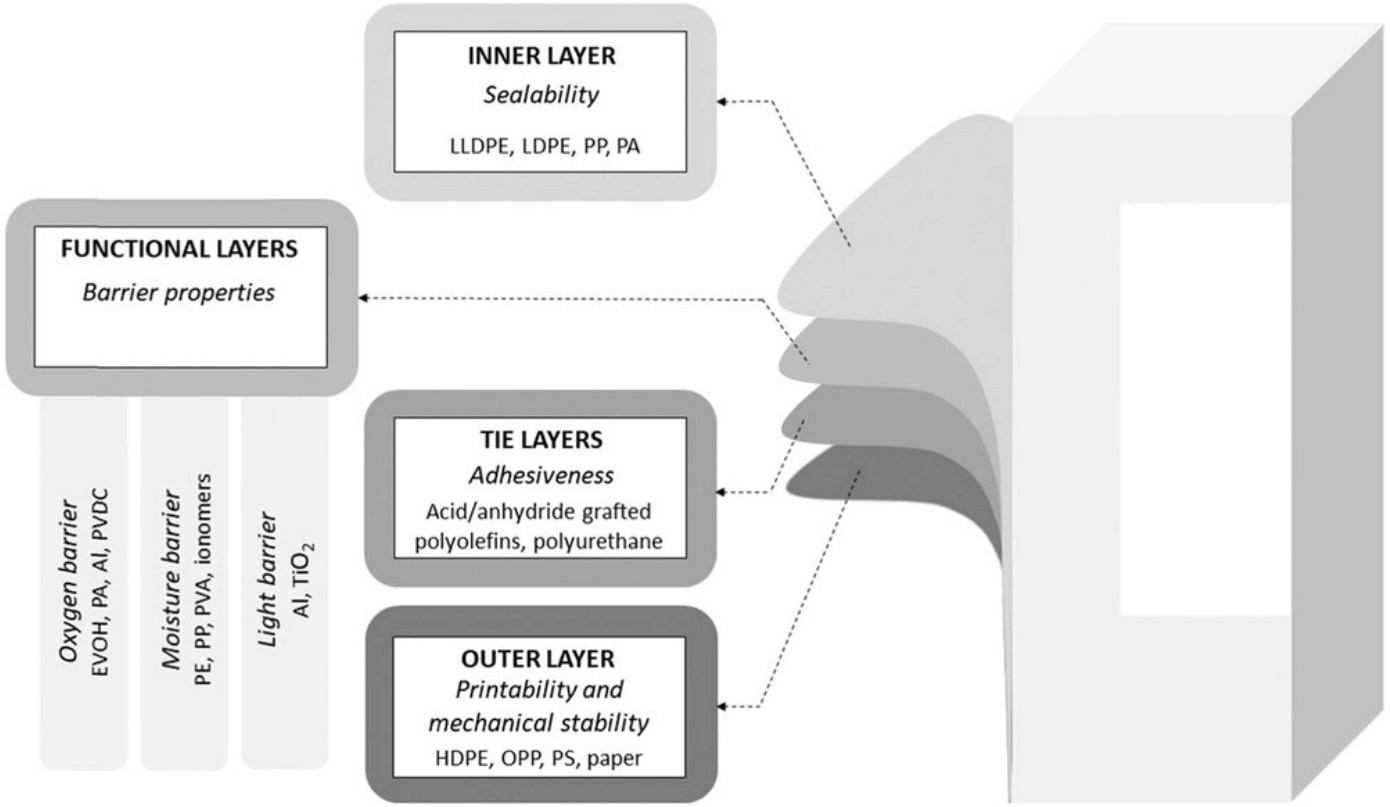
https://www.theverge.com/2014/6/10/5796310/illinois-bans-plastic-microbeads;

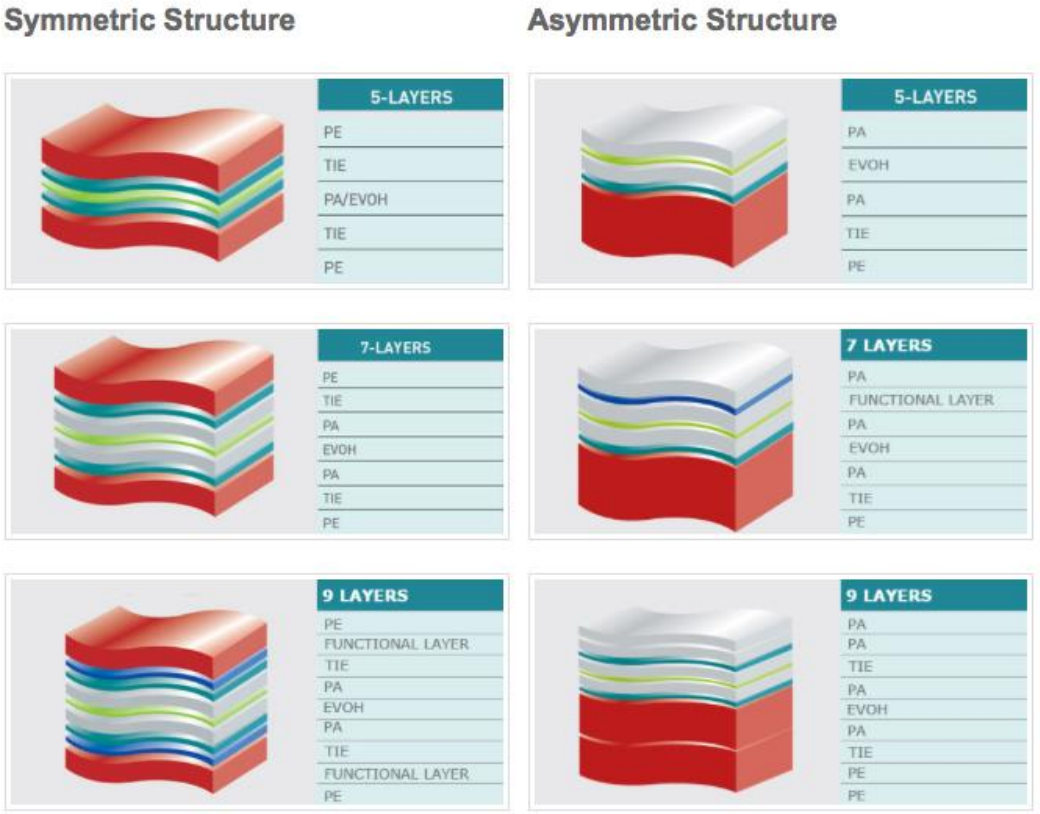
https://wedocs.unep.org/bitstream/handle/20.500.11822/33807/ARIC.pdf?sequence=1&isAllowed=y

Different Grouping of Plastics (6) - According to composition

According to their **compositions:**

- **Single-layer** *vs.* **multi-layer (or composite) plastics**

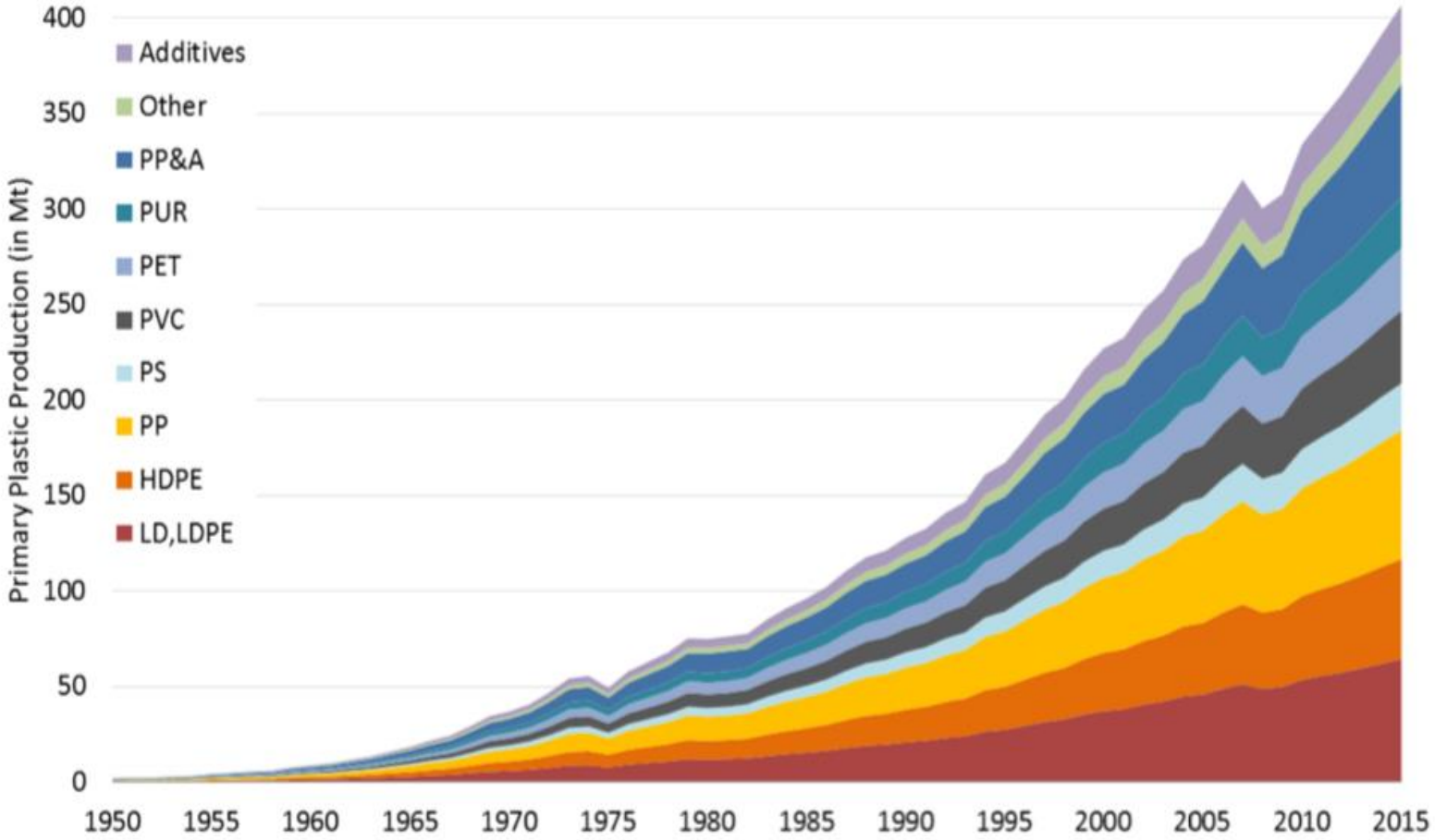




https://ift.onlinelibrary.wiley.com/doi/full/10.1111/1541-4337.12556

Major Plastics and Their Applications

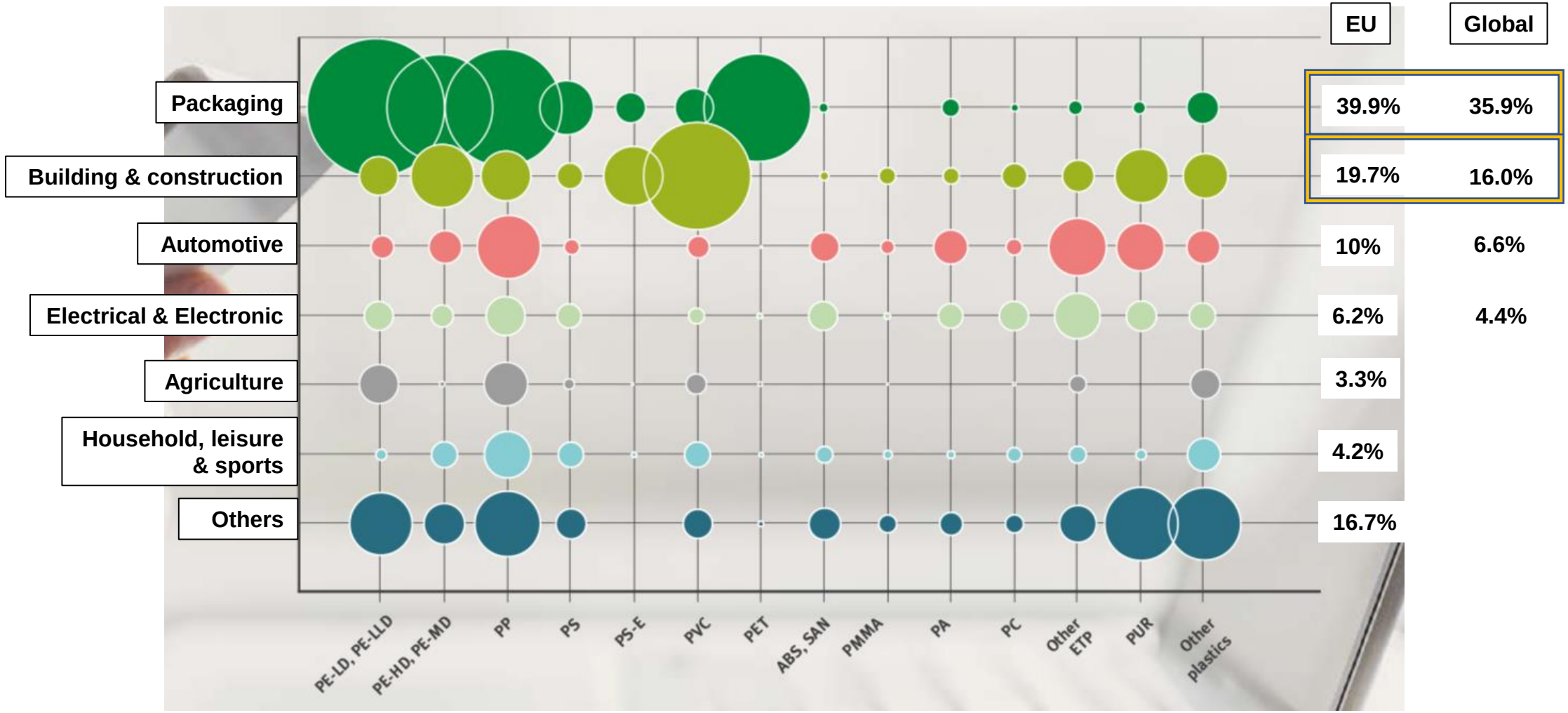
- Commodity plastics (PE, PP, PVC, PS&EPS, PET) = ca. 85–90% of the sum demand
- Engineering and other plastics = ca. 10% of the total demand



PlasticsEurope
https://committee.iso.org/files/live/sites/tc61/files/The%20Plastic%20Industry%20Berlin%20Aug%202016%20-%20Copy.pdf

Geyer et al. (2017)
10.1126/sciadv.1700782

Major Plastics and Their Applications



	EU	Global
Packaging	39.9%	35.9%
Building & construction	19.7%	16.0%
Automotive	10%	6.6%
Electrical & Electronic	6.2%	4.4%
Agriculture	3.3%	
Household, leisure & sports	4.2%	
Others	16.7%	

PlasticsEurope (2017) https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf;
Geyer et al. (2017) 10.1126/sciadv.1700782

International Resin Identification Coding System & Recyclability

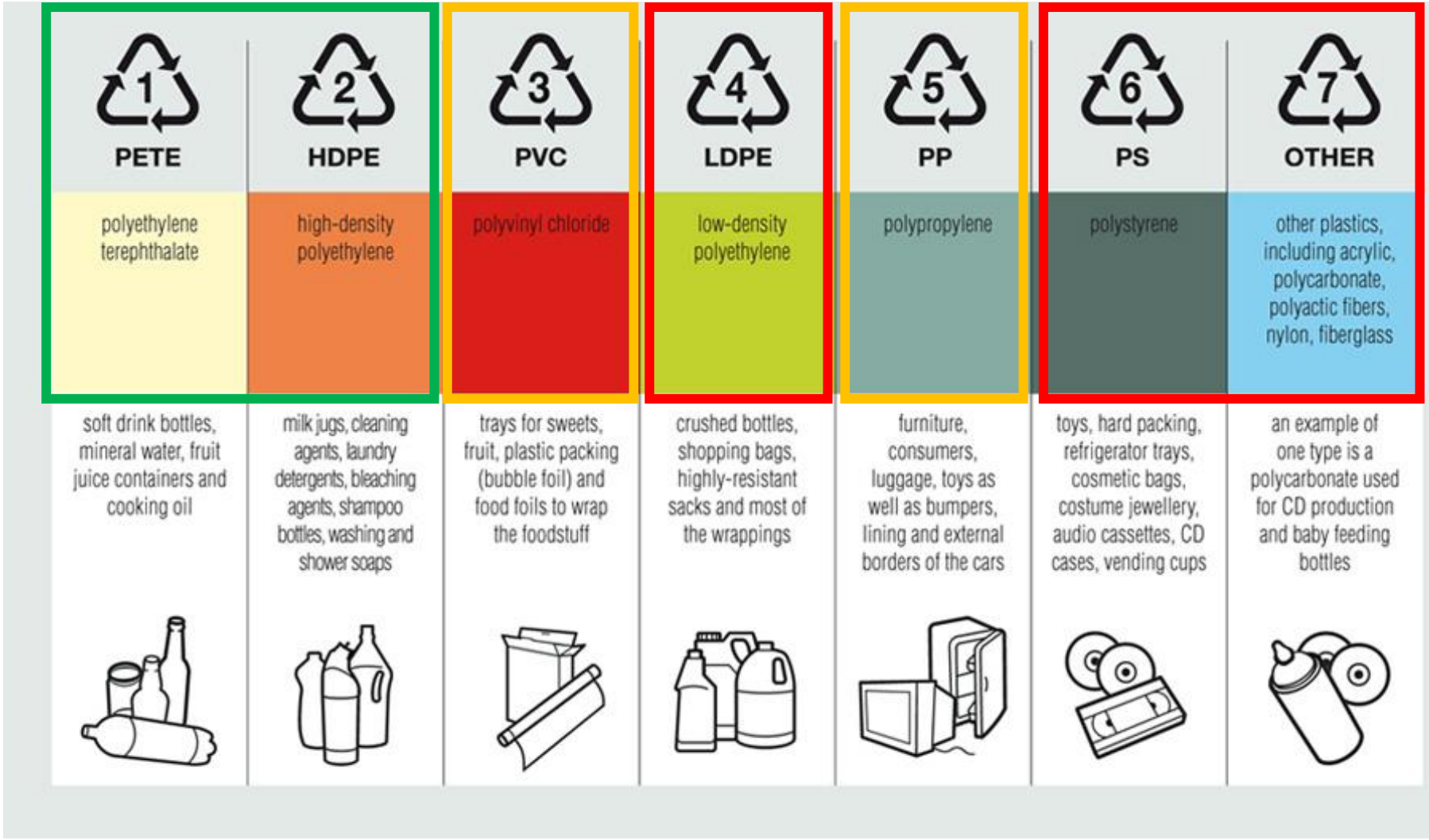
- The ASTM International Resin Identification Coding System (RIC) is a set of symbols appearing on plastic products that identify 6 major plastic resins out of which the product is made. And a seventh category of other plastics.

- The aim was to label plastic for recycling.
- **The numbers also indicate general ease of recycling** (including **cost-effectiveness**), with 1 and 2 being the easiest and 6 and 7 being very difficult (Hopewell et al. 2009)

Most easily and frequently recycled

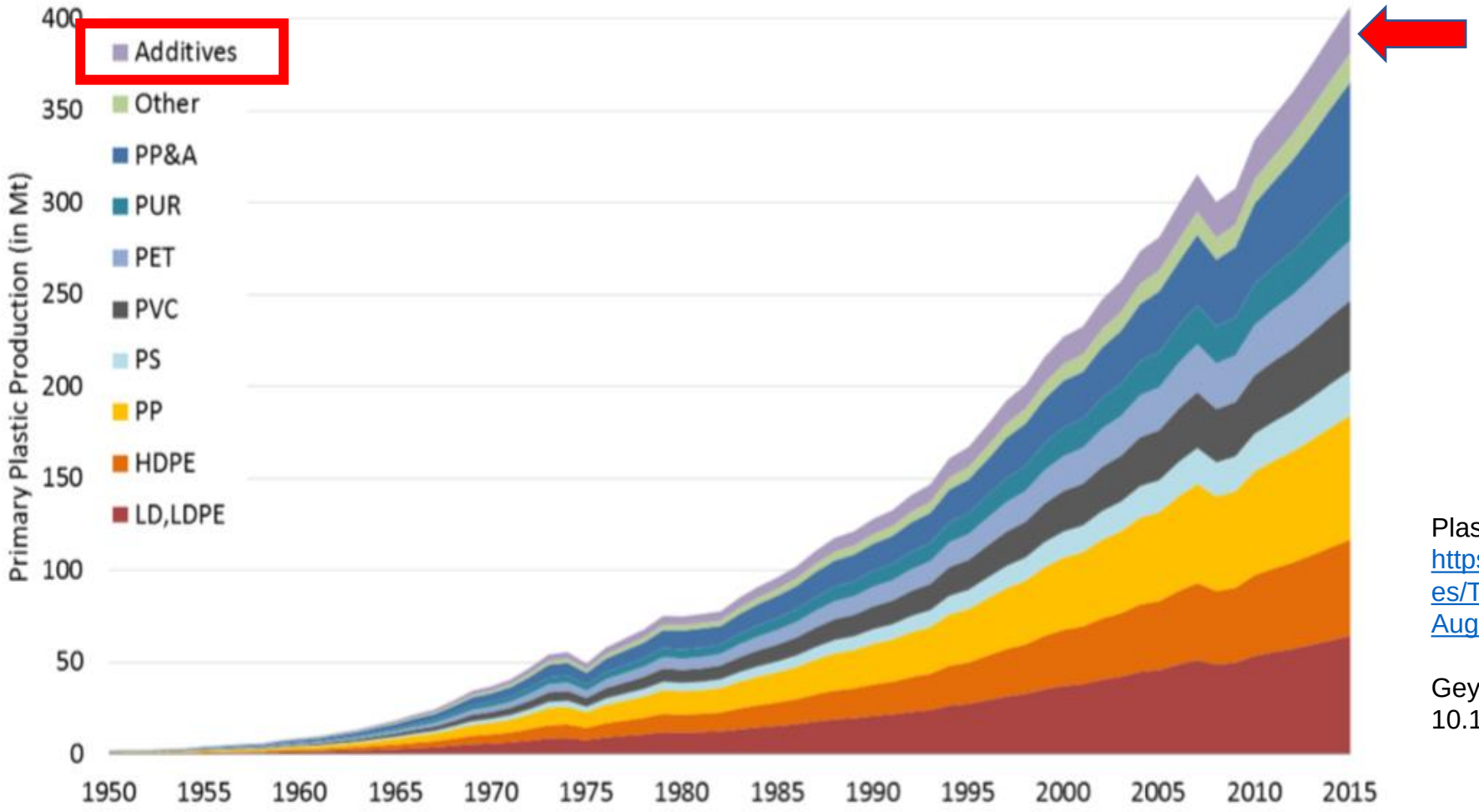
Sometimes recycled if a recycler is available to take/gather the plastic

Difficult and normally not recycled



Plastics and Additives

- On average, 4 weight% of plastics consists of additives (Bouwmeester et al., 2015),
- The exact levels can vary considerably (e.g., plasticizers can be up to 70 weight% of PVC)



PlasticsEurope
https://committee.iso.org/files/live/sites/tc61/files/The%20Plastic%20Industry%20Berlin%20Aug%202016%20-%20Copy.pdf

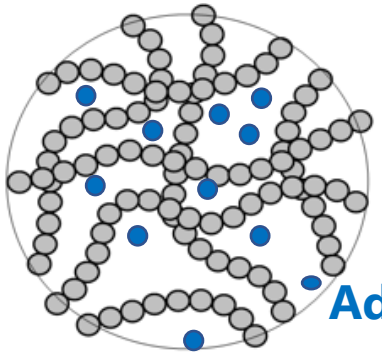
Geyer et al. (2017)
10.1126/sciadv.1700782

Why are plastic additives needed?

Chemical additives are substances added during the manufacturing process of plastic to enhance plastic performances, functionality, resistance against aging or aesthetic properties

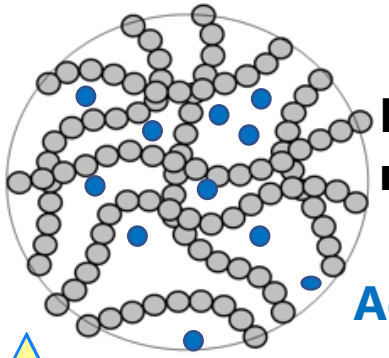
Two major roles of plastic additives

- **A) Stabilization:** to retain the original molecular structure and performance of the polymer under the effect of heat, light, etc.



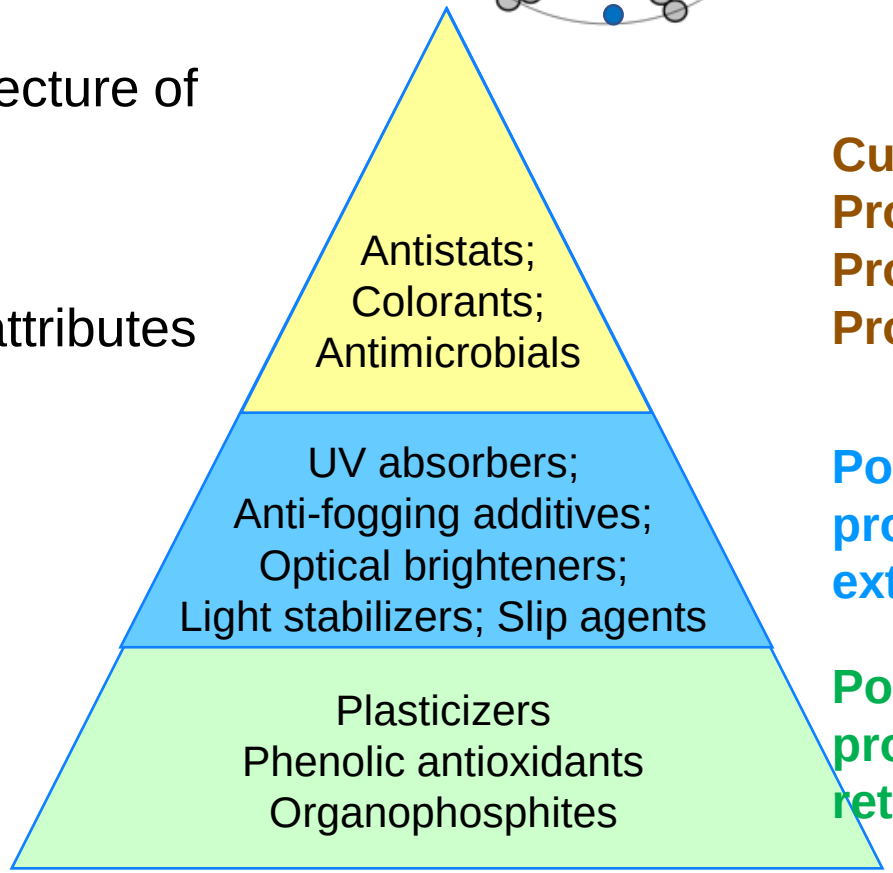
http://pqri.org/wp-content/uploads/2015/08/pdf/Polymer_Additives_PQRI_Poster.pdf
https://books.google.ch/books?id=Pwvtj9jJd6wC&lpg=PA187&dq=polymer%20property%20extension%20retention&hl=zh-CN&pg=PA187#v=onepage&q=polymer%20property%20extension%20retention&f=false

Why are plastic additives needed?



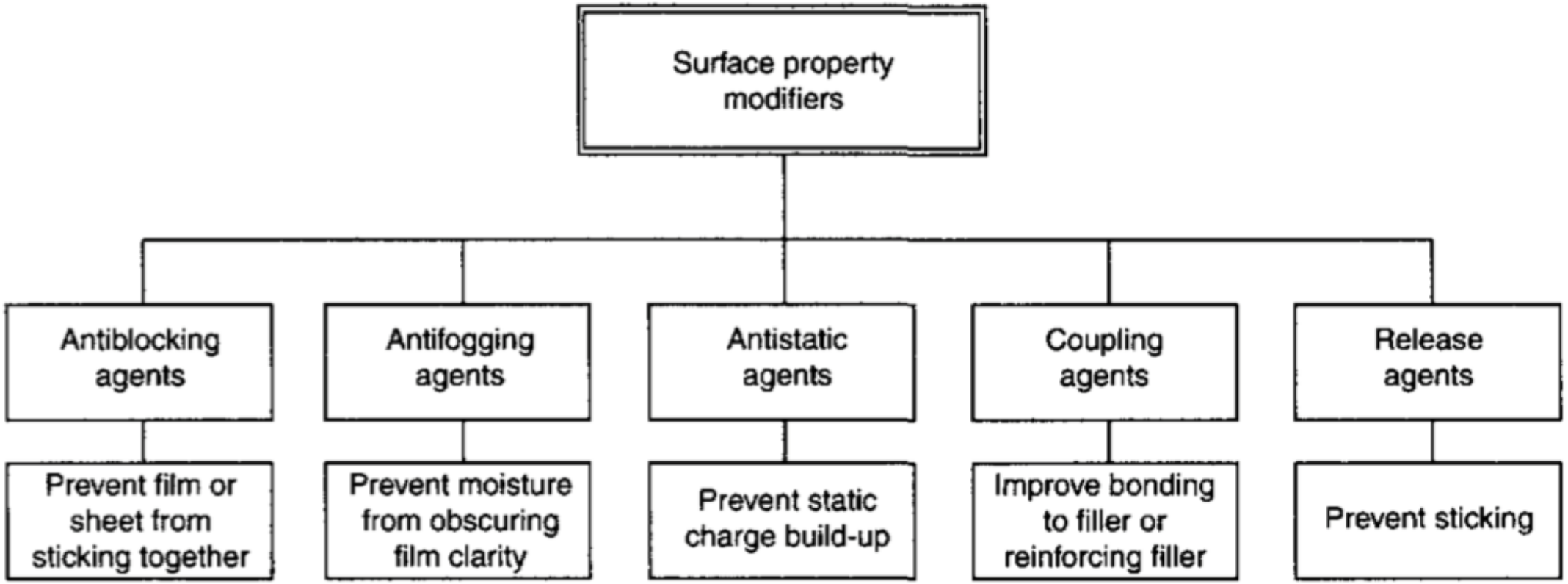
Two major roles of plastic additives

- **A) Stabilization:** to retain the original molecular architecture of the polymer under the effect of heat, light, etc.
- **B) Functionalization:** to provide additional functions/attributes to the polymer matrix



http://pqri.org/wp-content/uploads/2015/08/pdf/Polymer_Additives_PQRI_Poster.pdf
https://books.google.ch/books?id=Pwvtj9jJd6wC&lpg=PA187&dq=polymer%20property%20extension%20retention&hl=zh-CN&pg=PA187#v=onepage&q=polymer%20property%20extension%20retention&f=false

Different Types of Plastic Additives (1)



https://polymer-additives.specialchem.com/selection-guide/antiblock-agents-selection

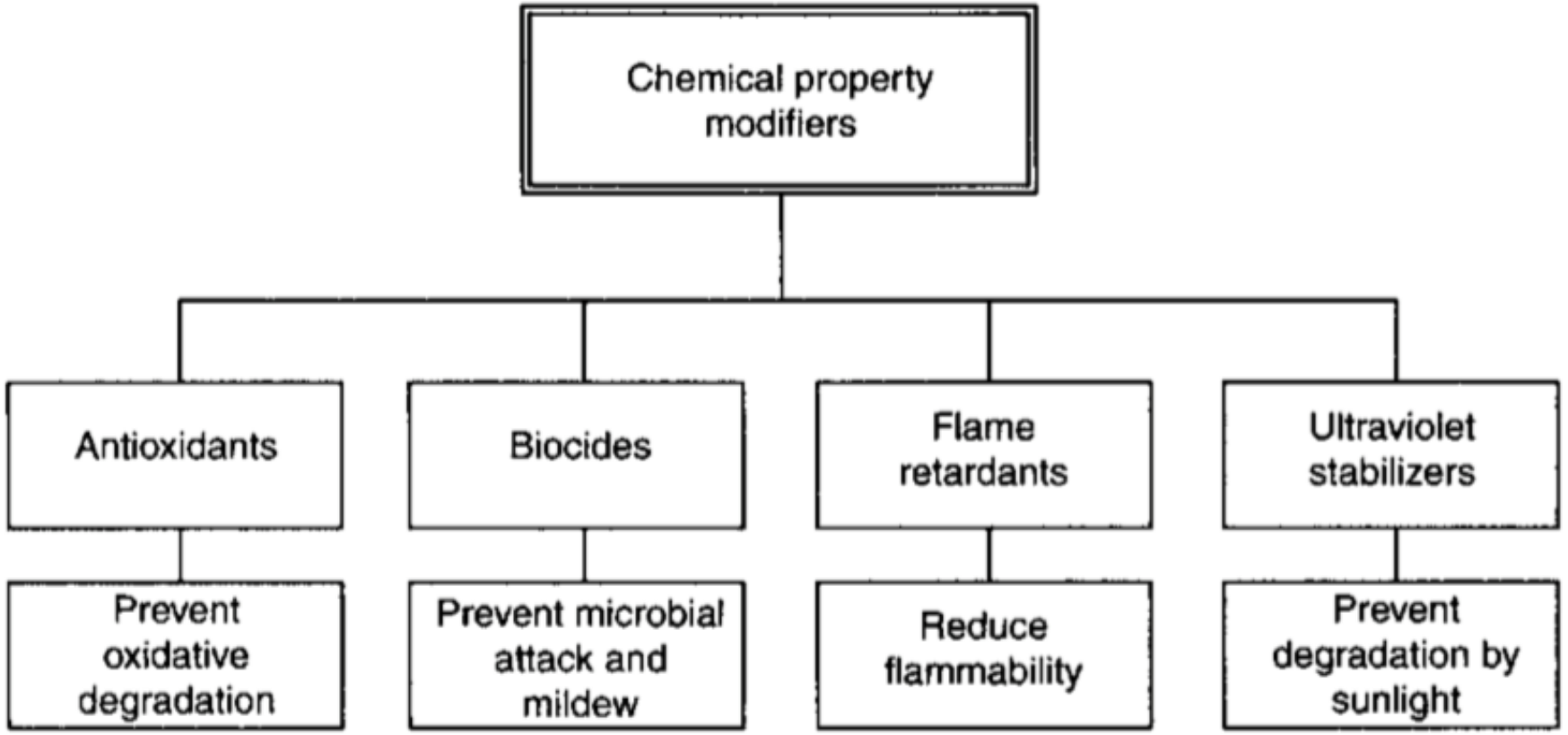
https://polymer-additives.specialchem.com/product-categories/additives-anti-fogging-agents

https://polymer-additives.specialchem.com/selection-guide/antistatic-agents-for-polymers

https://polymer-additives.specialchem.com/product-categories/additives-adhesion-promoters-compatibilizers-coupling-agents-compatibilizers

https://polymer-additives.specialchem.com/product-categories/additives-release-agents

Different Types of Plastic Additives (2)



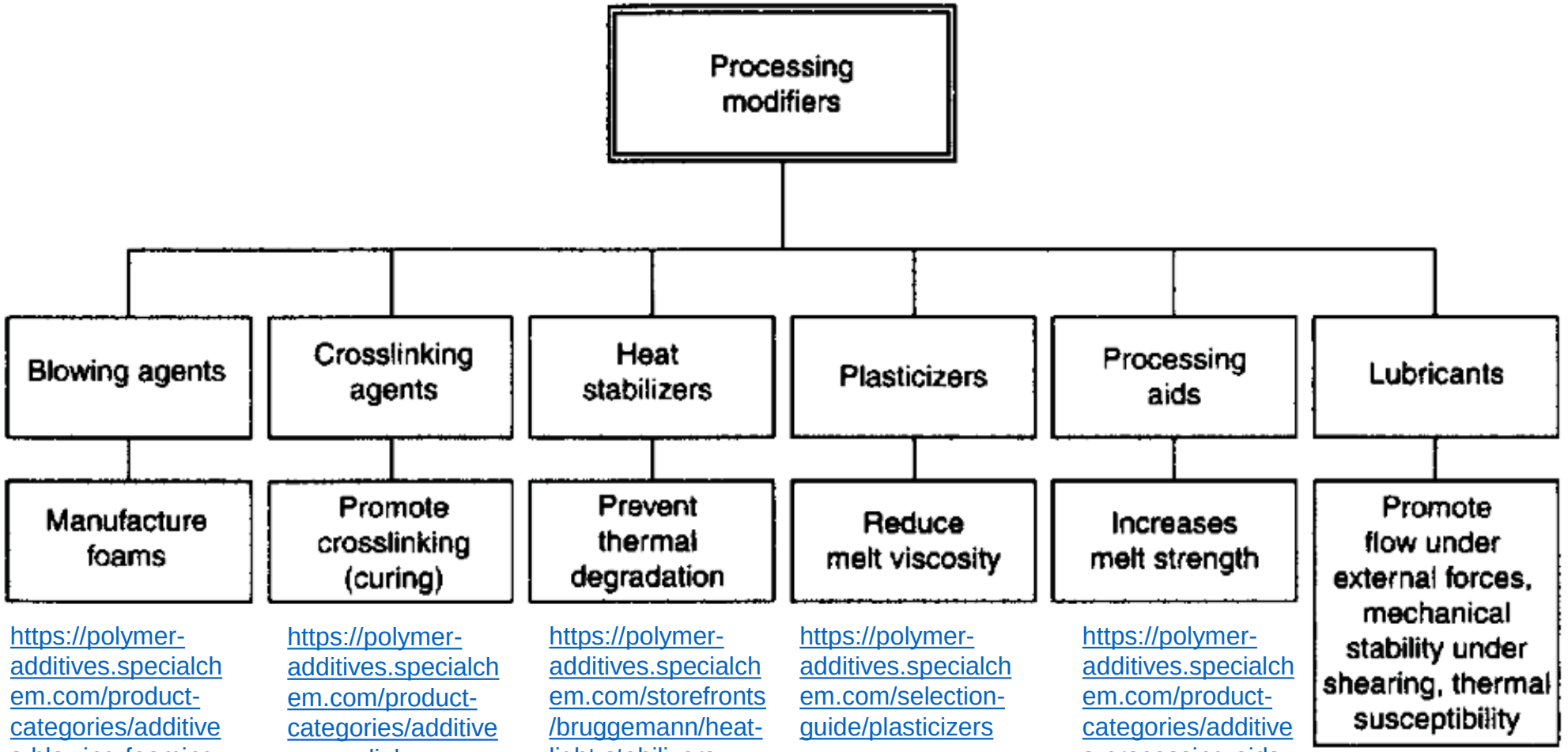
https://polymer-additives.specialchem.com/product-categories/additives-antioxidants

https://polymer-additives.specialchem.com/product-categories/additives-biocides-antimicrobial-agents

https://polymer-additives.specialchem.com/channel/flame-retardants

https://polymer-additives.specialchem.com/selection-guide/light-uv-stabilizers-selection-for-polymers

Different Types of Plastic Additives (3)



https://polymer-additives.specialchem.com/product-categories/additives-blowing-foaming-agents

https://polymer-additives.specialchem.com/product-categories/additives-crosslinkers-curing-agents-hardeners

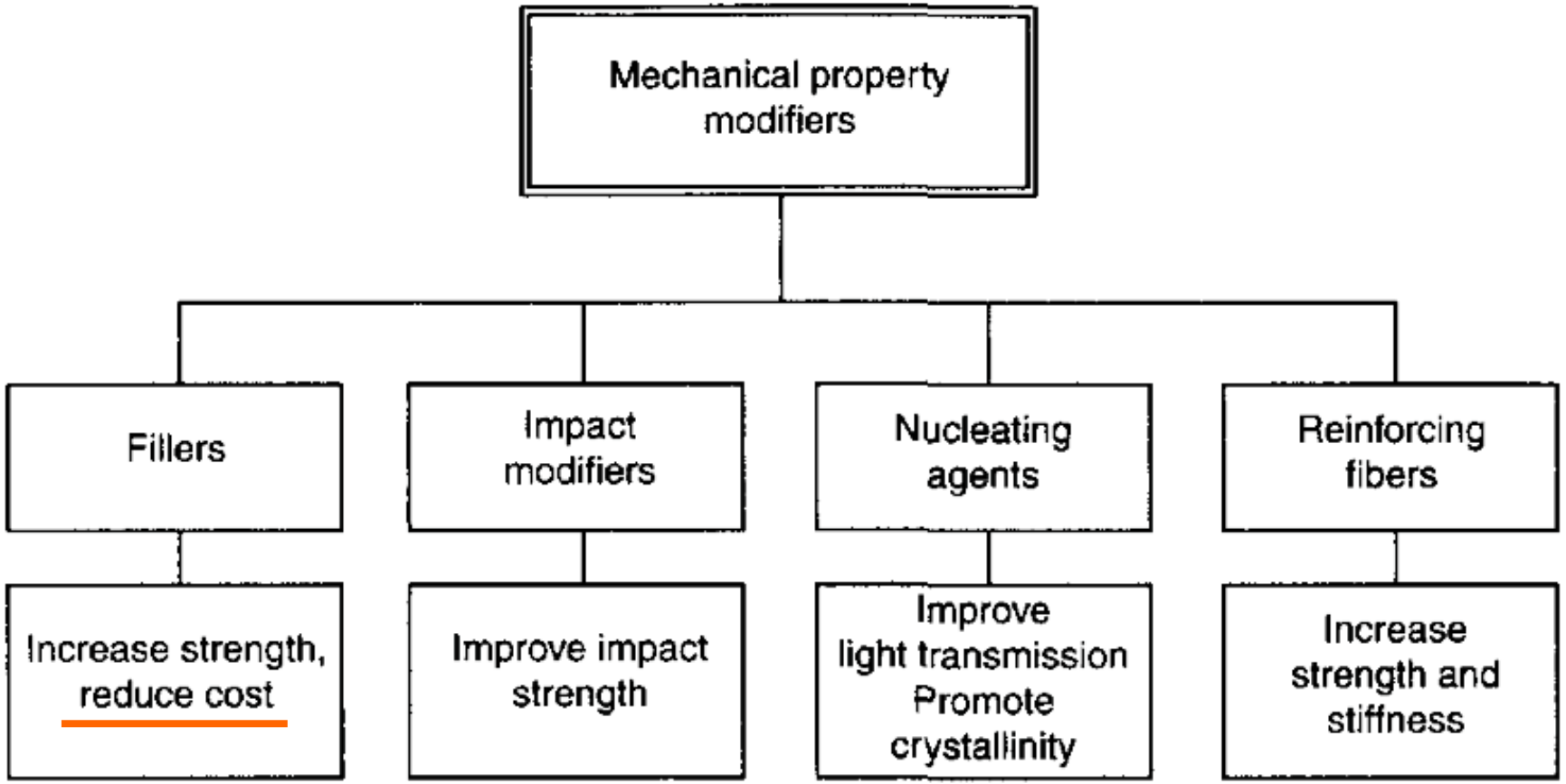
https://polymer-additives.specialchem.com/storefronts/bruggemann/heat-light-stabilizers-and-antioxidants

https://polymer-additives.specialchem.com/selection-guide/plasticizers

https://polymer-additives.specialchem.com/product-categories/additives-processing-aids

https://polymer-additives.specialchem.com/selection-guide/lubricants

Different Types of Plastic Additives (4)



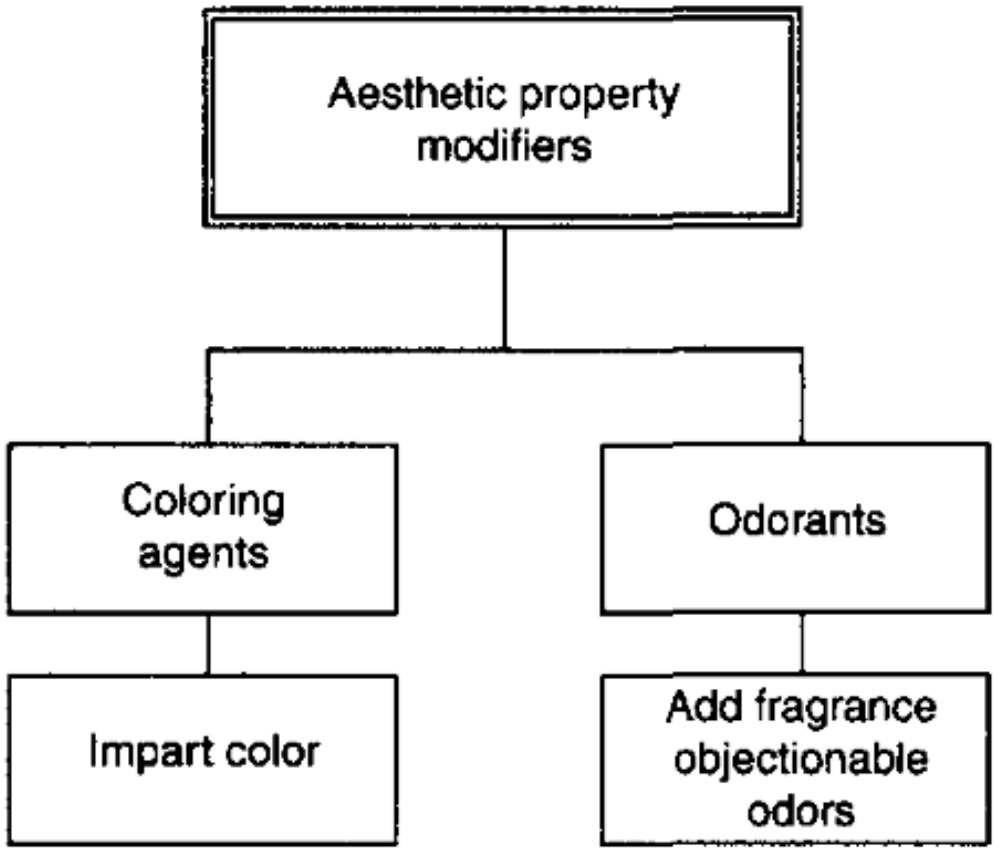
https://polymer-additives.specialchem.com/product-categories/additives-fillers

https://polymer-additives.specialchem.com/selection-guide/impact-modifiers-for-polymers

https://polymer-additives.specialchem.com/product-categories/additives-nucleating-agents

https://polymer-additives.specialchem.com/product-categories/additives-fibers

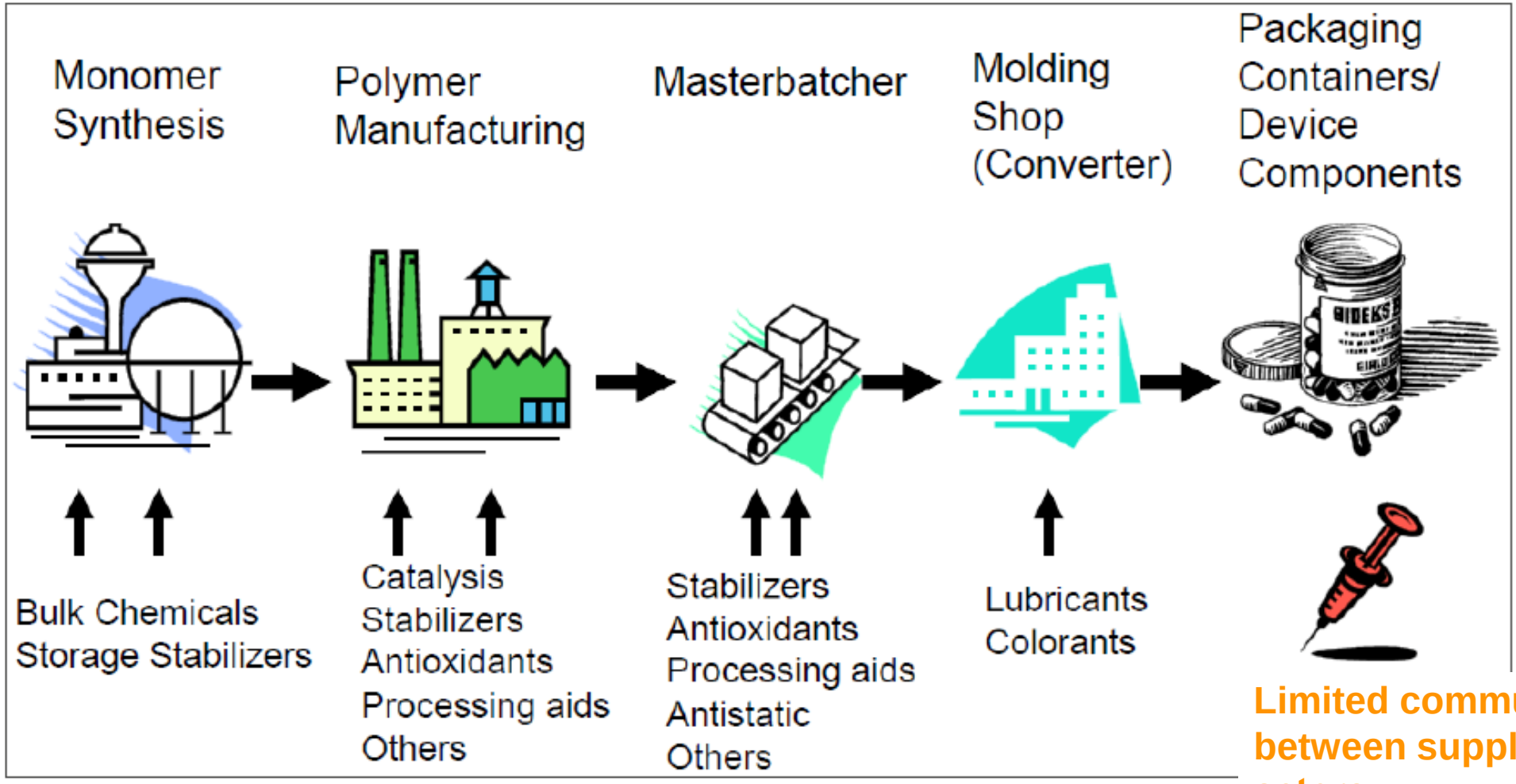
Different Types of Plastic Additives (5)



https://polymer-additives.specialchem.com/selection-guide/pigments-for-plastics

https://polymer-additives.specialchem.com/product-categories/additives-deodorants-fragrances

Additives are Added in Every Step of the Production



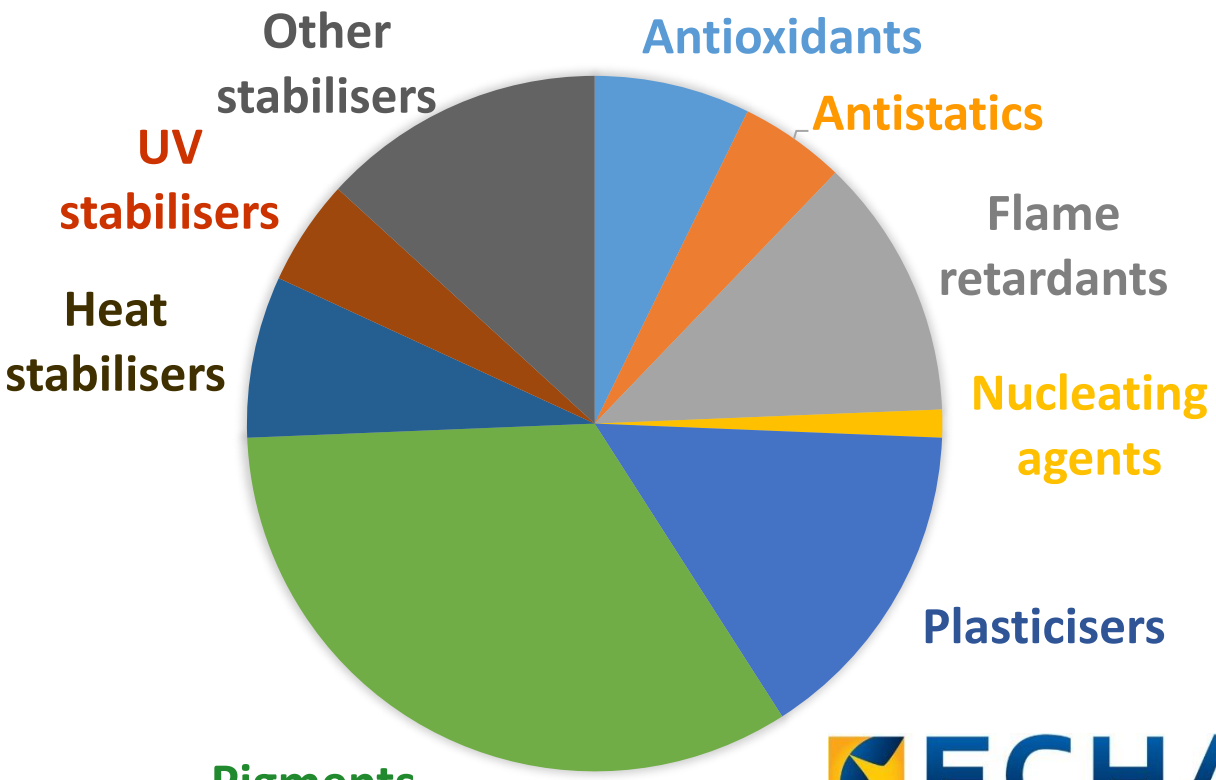
Cindy Zweiben, Pfizer, Inc., Characterization of Extractables and Leachable in Parenteral Drug Products

Limited communication between supply-chain actors …

Plastic contain a wide range of chemical additives

- 9 major types of functional additives & pigments (ECHA assessment).

- Plastic frequently contain 6 additives and more; some are hazardous.
- EU: 418 high volume plastic additives (above 100 t/yr).



ECHA Assessment
https://echa.europa.eu/plastic-additives-initiative

ECHA
EUROPEAN CHEMICALS AGENCY

UNEP study on chemicals in plastics contributing to Plastic Treaty Process

IPCP has prepared for UNEP a report on chemicals in plastics with following key findings:

- More than 13,000 chemicals are present in plastics.
- More than 3,200 are chemicals of potential concern (with certain hazard properties considering GHS/CLP).
- Need of a better life cycle management and control.
- Need of non-toxic alternatives for clean material cycles.

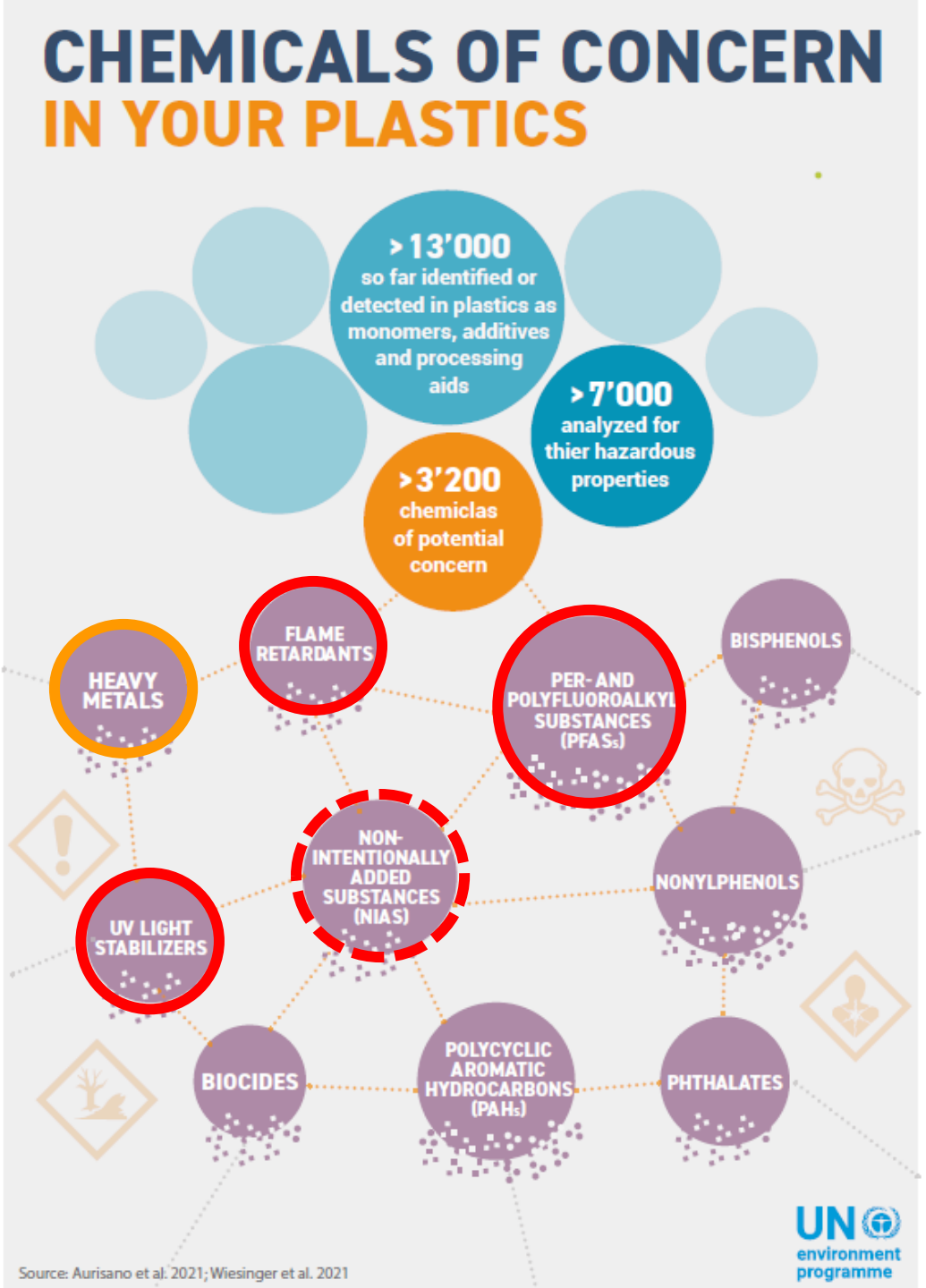
Available online at www.sciencedirect.com
ScienceDirect
Current Opinion in Green and Sustainable Chemistry
https://doi.org/10.1016/j.cogsc.2021.100513

Enabling a circular economy for chemicals in plastics

Nicolò Aurisano[1], Roland Weber[2] and Peter Fantke[1]

Deep Dive into Plastic Monomers, Additives, and Processing Aids
Helene Wiesinger,* Zhanyun Wang,* and Stefanie Hellweg
https://doi.org/10.1021/acs.est.1c00976
Environmental Science & Technology

IPCP International Panel on Chemical Pollution



Thank you for your attention !

More Information

UNEP Plastics Treaty: https://www.unep.org/about-un-environment/inc-plastic-pollution

Basel Convention: www.basel.int

Stockholm Convention: http://chm.pops.int/

Rotterdam Convention: www.pic.int

SAICM: http://www.saicm.org/

OECD/IOMC: http://www.oecd.org/chemicalsafety/

Industry: https://endplasticwaste.org/; http://www.suschem.org/

Science: www.ipcp.ch; https://www.plasticstreaty.org/scientists-declaration/

NGO: www.ban.org; www.ipen.org; https://www.ciel.org/; www.chemsec.org

Better-world-links: http://www.betterworldlinks.org/

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