An overview of plastics

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Outline

- LYB highlights
- Plastics vs Polymers
- What are plastics
  - Classes
  - Types of plastics and uses
- Additives
  - Use and Function
- Summary

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Sustainable solutions for everyday living

Cleaner air & fuel efficiency

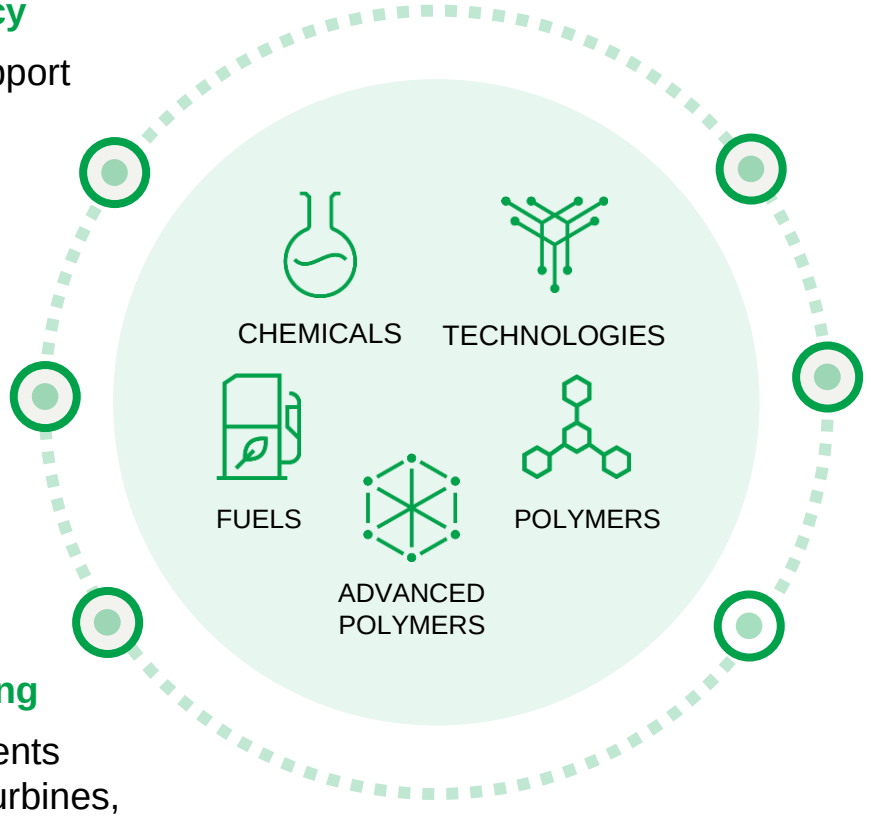
Stronger, lighter plastics support increased fuel efficiency

Food safety & access

Food packaging and films that improve freshness, portability and extend shelf-life

Sustainable & modern living

Materials that form components used in solar panels, wind turbines, children's toys, cosmetics, leak- and shatter-proof containers



Potable water delivery

Stronger, longer-lasting pipes used in municipal water systems and key elements used in water filtration systems

Quality healthcare

Essential medical supplies such as surgical face masks, hand sanitizers, biohazard bags and pill coatings

Agricultural efficiency

Lighter machinery, crop protection and soil conditioning used to be more efficient in agro-processing

Our industry-leading sustainability ambitions and actions

Leading the way to profitably advance and innovate sustainable solutions

Ending plastic waste

- **2 MMt+**
  of recycled and renewable-based polymers produced and marketed annually by 2030[1]
- **for every $**
  we will invest in venture funds that address the plastic waste challenge, we help catalyze $5 from co-investors
- **zero**
  plastic pellet loss to the environment from our facilities

Taking climate action

- **net zero**
  greenhouse gas emissions from operations by 2050[2]
- **42%**
  absolute scope 1 and 2 greenhouse gas emissions reduction from operations by 2030[3]
- **30%**
  absolute scope 3 greenhouse gas emissions reduction by 2030[3]
- **50%**
  minimum of electricity produced from renewable sources by 2030[4]

Supporting a thriving society

- **zero**
  incidents, injuries and accidents
- **achieve**
  gender parity in senior leadership globally by 2032
- **increase**
  the number of people from underrepresented groups in U.S. senior leadership roles to reflect the general population ratio by 2032
- **assess**
  a minimum of 70% of our key suppliers globally using sustainability criteria by 2025

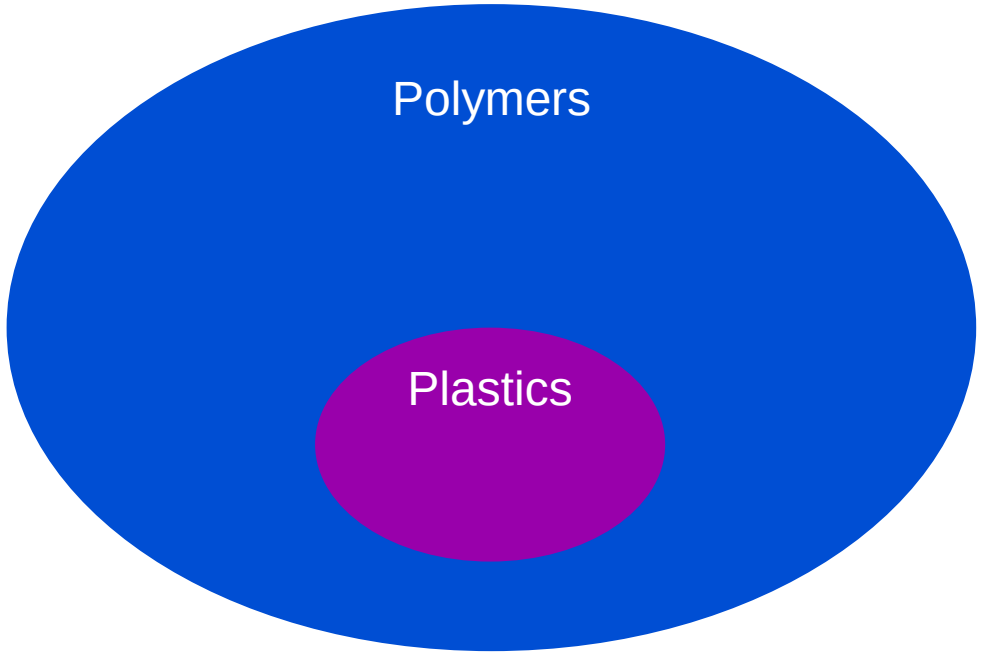
1. Million metric tons. Production and marketing includes: (i) joint venture production marketed by LYB plus our pro rata share of the remaining production produced and marketed by the joint venture, and (ii) production via third-party tolling arrangements.
2. Our 2050 net zero greenhouse gas emissions goal includes scope 1 and 2 emissions.
3. Relative to a 2020 baseline.
4. Based on 2020 procured levels.

Polymers vs Plastics

- Polymer – A large molecule made up of repeating smaller units called monomers
- Plastics – A polymeric material that can be molded or shaped when heated and hardened

- All plastics are polymers but not all polymers are plastics

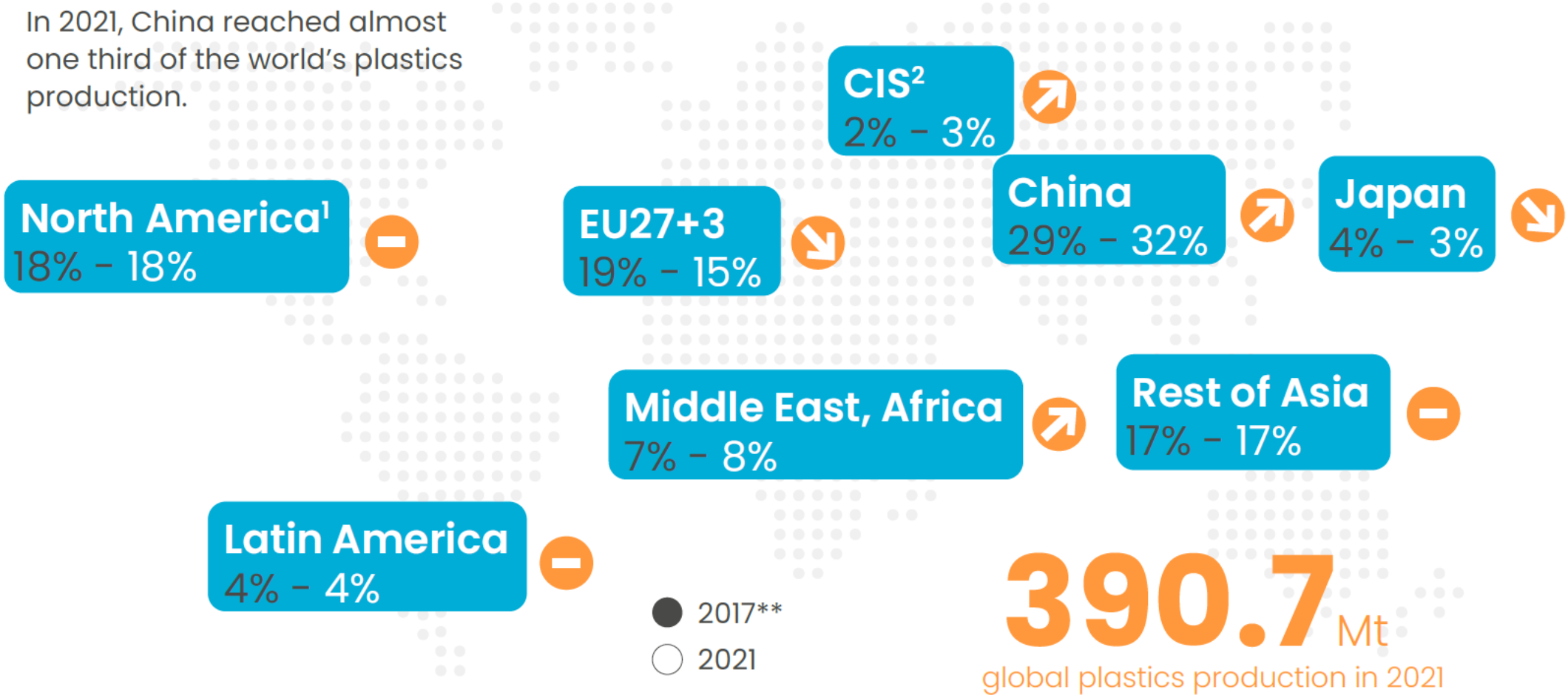
- From Merriam Webster: any of numerous organic synthetic or processed materials that are mostly thermoplastic or thermosetting polymers of high molecular weight and that can be made into objects, films, or filaments.



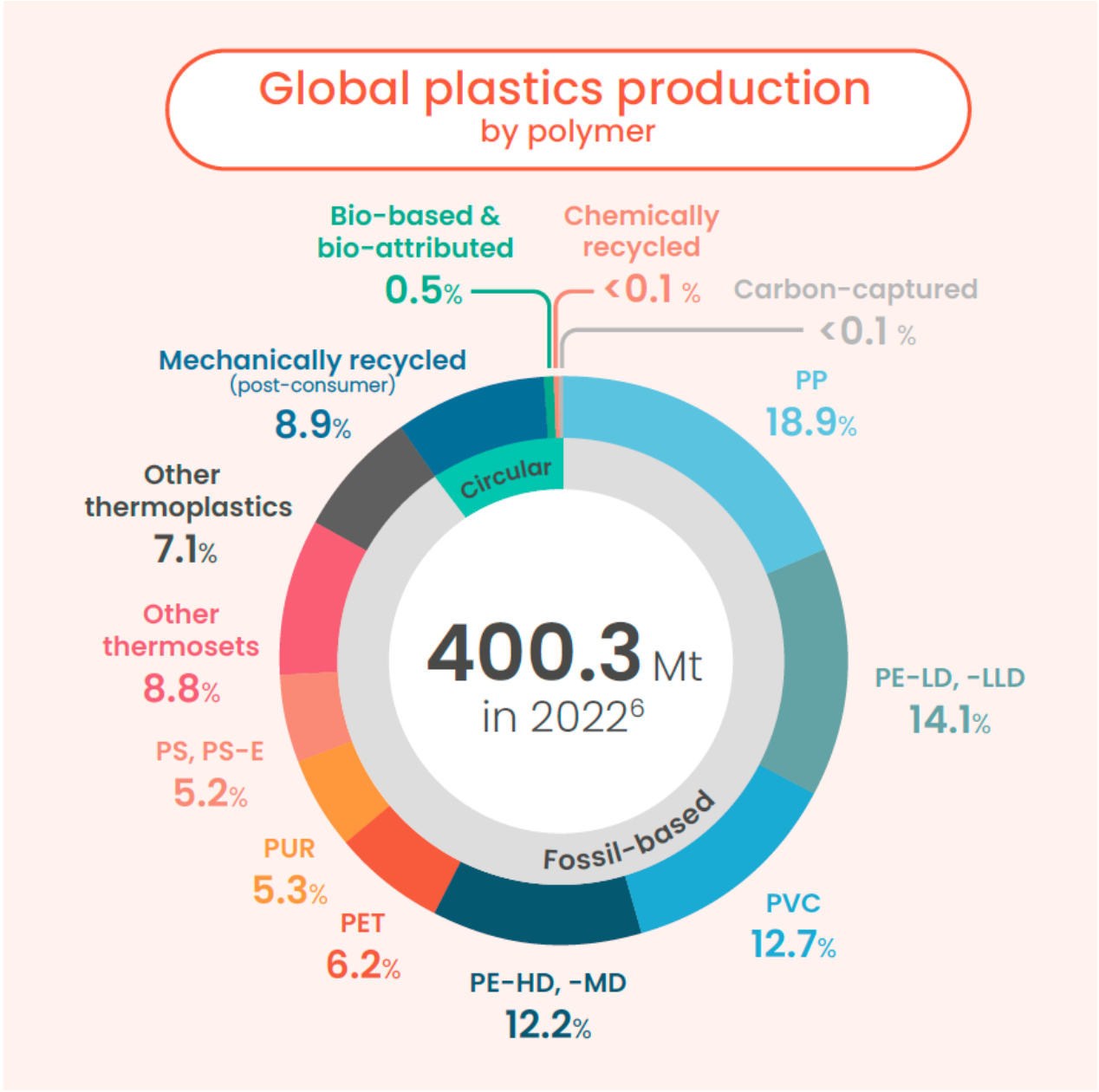
(https://www.merriam-webster.com/dictionary/plastic)

Distribution of the global plastic production

In 2021, China reached almost one third of the world's plastics production.



Source: Plastics Europe: Plastics – The facts 2022 (October 2022)



Source: Plastics Europe: Plastics – The facts 2022 (October 2022)

What are plastics: Classes

- Plastics can be divided into several classes as shown below – they are not mutually exclusive:

  - **Thermoplastics** - Plastics that can be melted and reshaped repeatedly without undergoing any significant chemical change
  - **Thermoset** - Plastics that undergo a chemical change when heated, hardening permanently and cannot be remolded after they are set.
  - **Elastomers** - Polymers that have elasticity, meaning they can stretch and return to their original shape without permanent deformation.
  - **Biodegradable Plastics** - Plastics that can be broken down by natural processes such as composting or microbial activity.
  - **Bioplastics** - Plastics derived from biological sources, such as plant-based materials, instead of fossil fuels.
  - **Engineering Plastics** - High-performance plastics designed to withstand mechanical and thermal stress, used in more demanding applications.

Engineering plastics

Polymer name	Key attributes	Notable applications
Polyetheretherketone (PEEK)	High strength, heat and chemical resistance	Aerospace, medical implants, automotive
Polytetrafluoroethylene (PTFE)	Low friction, heat and chemical resistance	Gaskets, non-stick coatings, electrical insulation
Polyimides (PI)	High temperature resistance	Electronics and aerospace
Polyphenylene Sulfide (PPS)	High strength and chemical resistance	Automotive, electronics and industrial components
Polyetherimide (PEI)	High strength, flame resistance, thermal stability	Electronics and medical devices
Liquid Crystal Polymers (LCPs)	Precision molding capabilities and strength	Electronics, connectors and fiber optics
Polyamide-imide (PAI)	High strength and heat and mechanical resistance	Aerospace and automotive
Polyaryletherketone (PAEK)	High heat and chemical resistance	Extreme Industrial applications

Bioplastics

•**Definition**: Plastics derived from biological sources, such as plant-based materials, instead of fossil fuels.

•**Characteristics**: Can be biodegradable or non-biodegradable.

•**Examples**:

- **Polylactic Acid (PLA)**
- **Bio-based Polyethylene (Bio-PE)**
- **Polybutylene Succinate (PBS)**

Image from Google Imagen 3 AI

Biodegradable

•**Definition**: Plastics that can be broken down by natural processes such as composting or microbial activity.

•**Characteristics**: Environmentally friendly, often derived from renewable resources.

•**Examples**:

- **Polylactic Acid (PLA)**
- **Polyhydroxyalkanoates (PHA)**
- **Starch-based plastics**

Image from Google Imagen 3 AI

Elastomers

•**Definition**: Polymers that have elasticity, meaning they can stretch and return to their original shape without permanent deformation.

•**Characteristics**: Flexible, resilient, often used in rubber-like products.

•**Examples**:

- **Natural rubber**
- **Synthetic rubber** (e.g., SBR - Styrene-Butadiene Rubber)
- **Silicone**
- **Neoprene**

Image from Google Imagen 3 AI

Thermoset plastics

- **Definition**: a synthetic material that hardens when heated and becomes permanently solid
- **Examples**
  - **Epoxy:** Used for adhesives, coatings and electrical components.
  - **Polyester resins:** Used for fiberglass, automotive parts and boat hulls.
  - **Phenolic resins:** Used for electrical insulators, adhesives and laminates.
  - **Urea-formaldehyde:** Used for plywood, particleboard and adhesives.
  - **Melamine-formaldehyde:** Used for dinnerware, countertops and laminate flooring.
  - **Polyurethane**: used for seals, gaskets and shock absorbers
  - **Bakelite**: used for electrical components, household items and automotive parts

Image from Google Imagen 3 AI

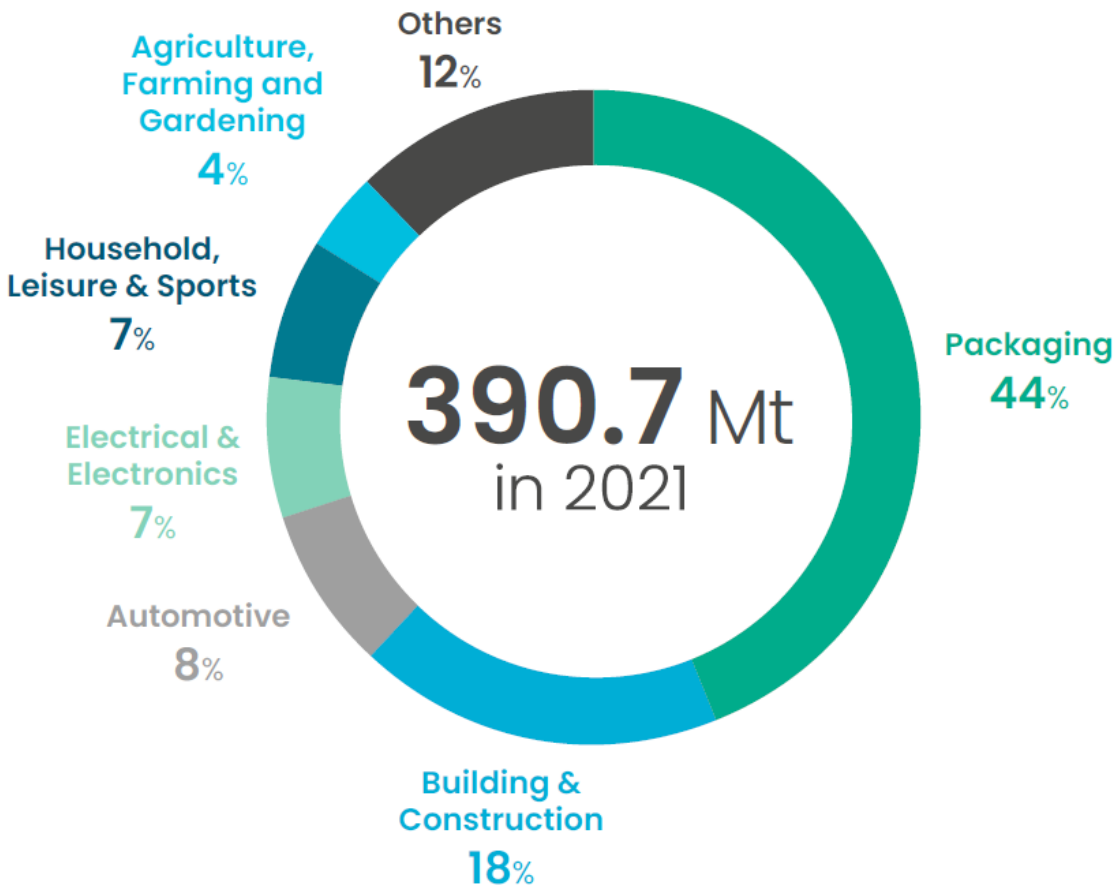
Thermoplastics

Polymer name	Typical applications
Low Density Polyethylene (LDPE) / Linear Low Density Polyethylene (LLDPE)*	Plastic bags, cling wrap and bubble wrap
High Density Polyethylene (HDPE)*	Milk jugs, detergent bottles, cereal box liners, pipes, toys
Polypropylene (PP)*	Yogurt containers, plastic lids, automotive parts, medical applications
Polyethylene Terephthalate (PET)	Beverage bottles, food packaging and polyester clothing
Polyvinyl Chloride (PVC)	Pipes, flooring and window frames
Acrylonitrile Butadiene Styrene (ABS)	Lego bricks, plumbing fixtures, automotive parts
Polyamide (PA, Nylon)	Carpet fibres, clothing, automotive
Polycarbonate (PC)	Compact discs, safety glasses, automotive parts

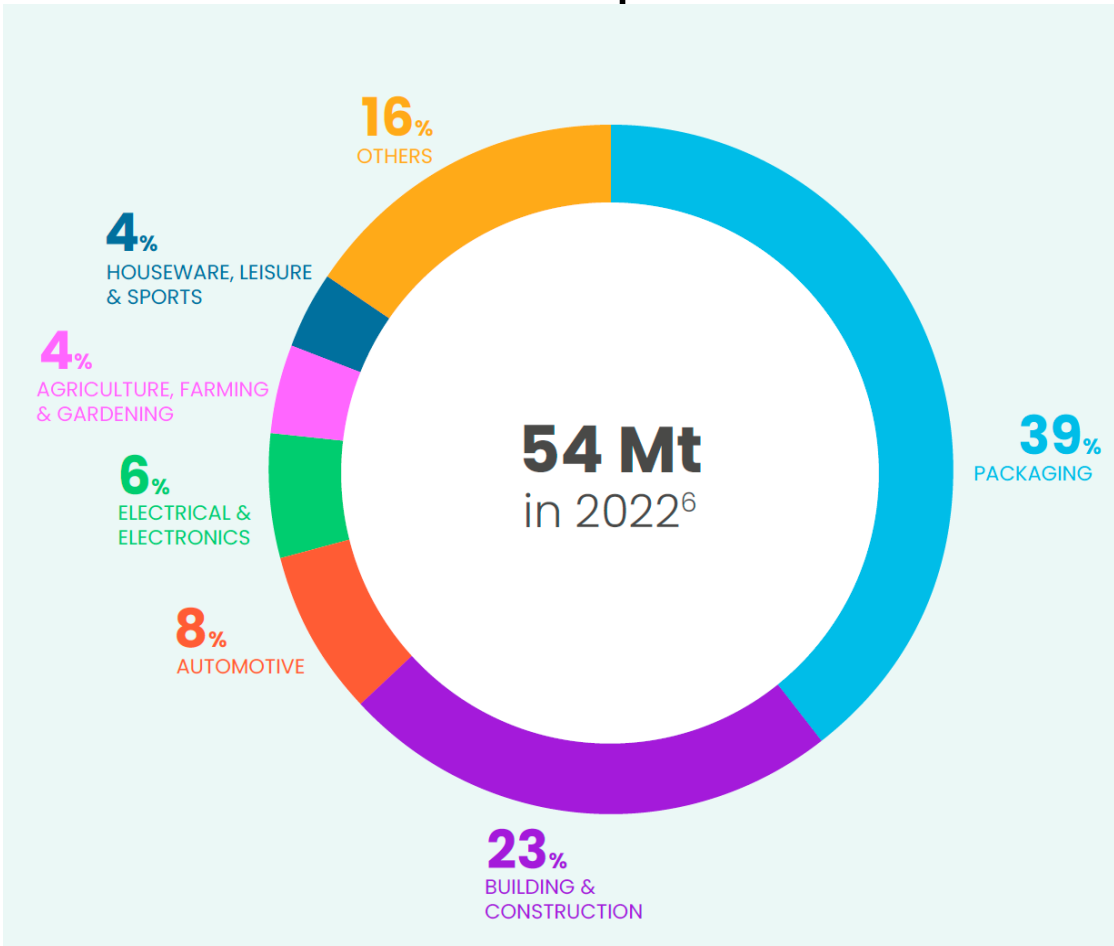
*Polyolefins

Use of plastics by sector

Global



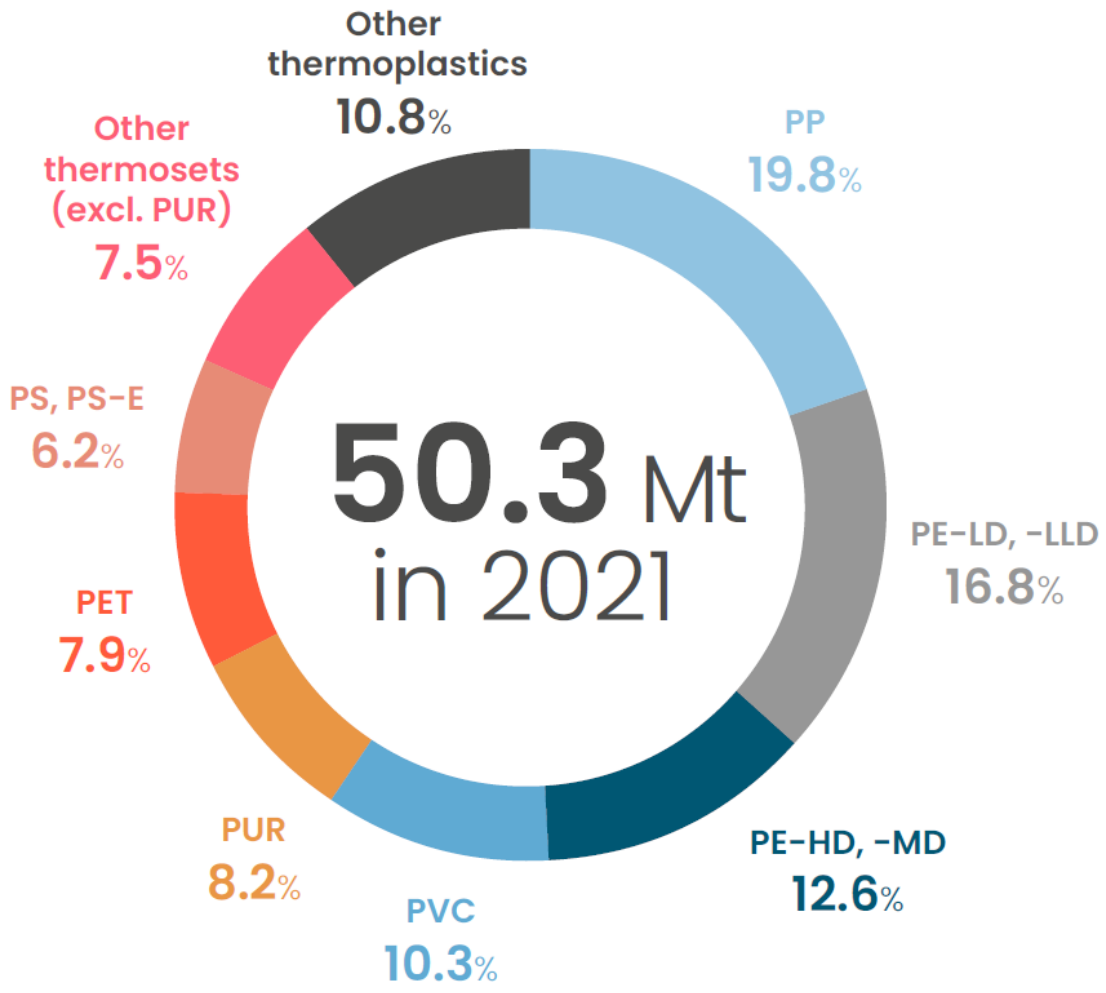
European



Source: Plastics Europe: Plastics the Facts 2022 (October 2022)

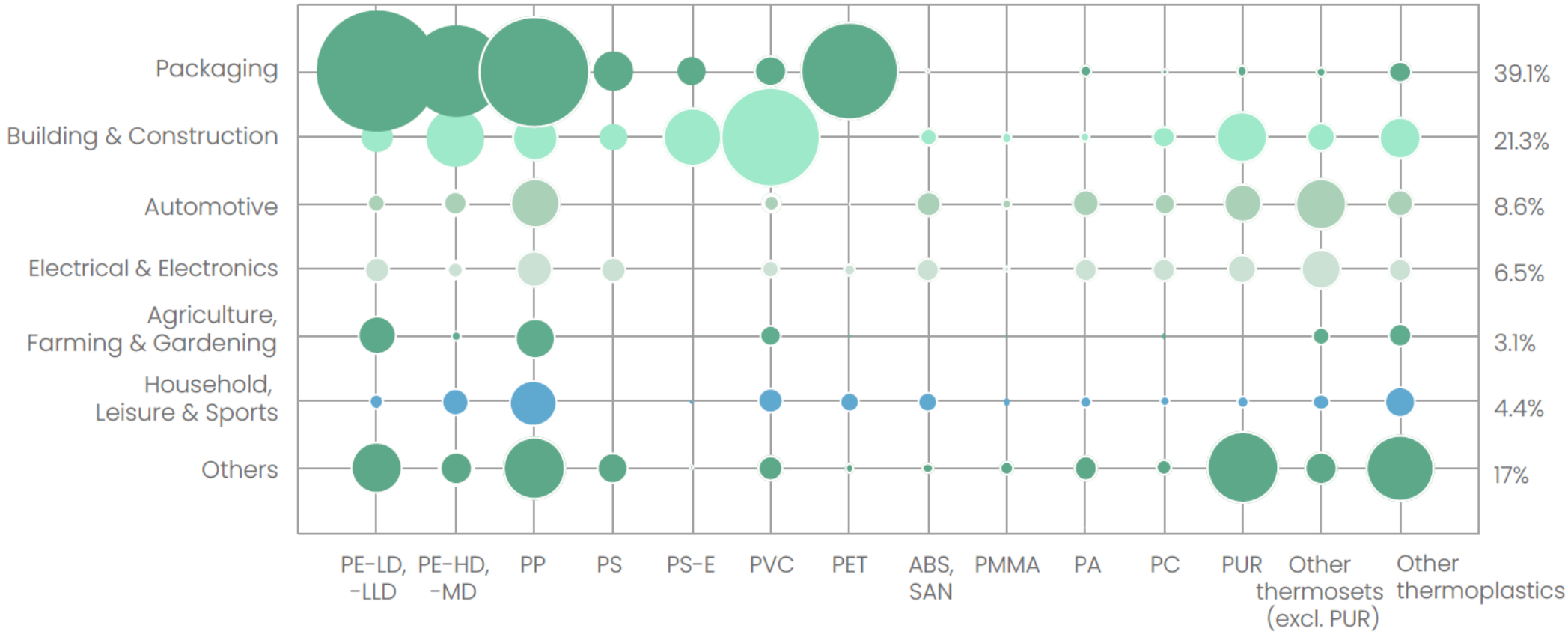
European plastics converters' demand by type

In 2021, almost half of the European plastics converters' demand was represented by polyolefins.



Source: Plastics Europe: Plastics the Facts 2022 (October 2022)

European plastics converters' demand by application and type

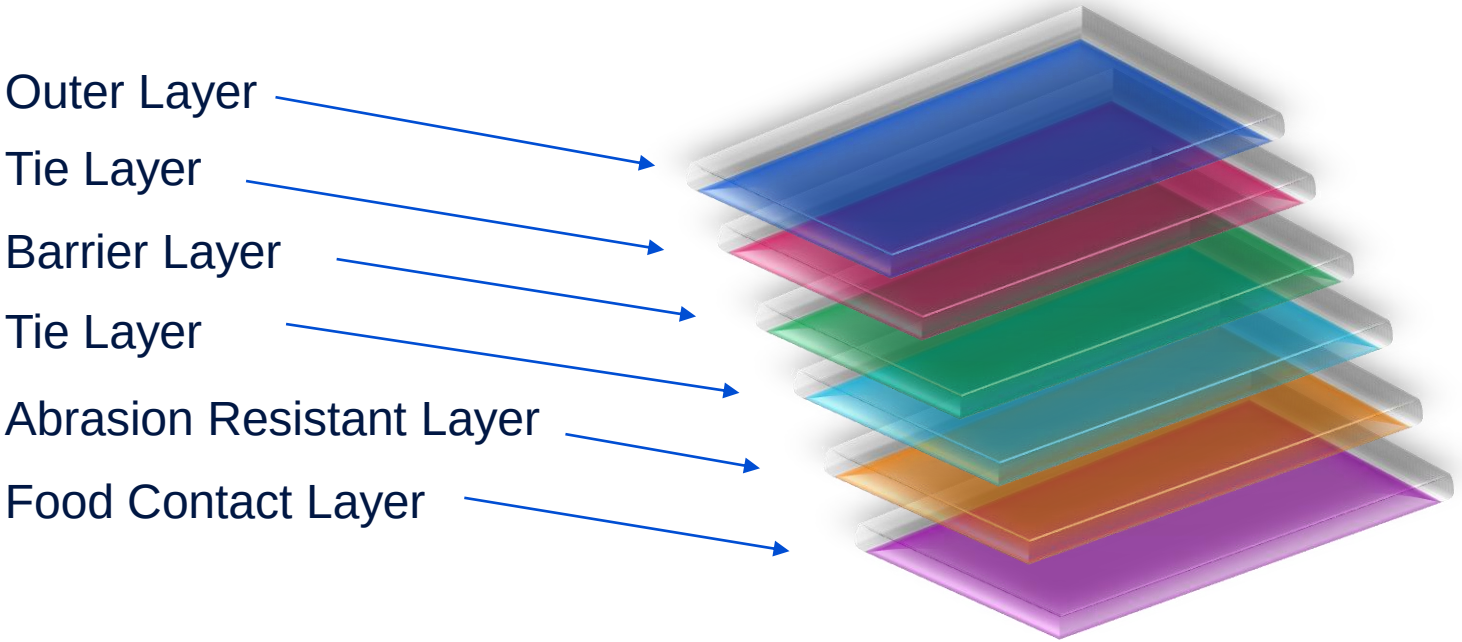


Source: Plastics Europe: Plastics the Facts 2022 (October 2022)

Polymer selection – What drives selection

- Polymer resin availability may be the biggest driver
- Polymer technical performance factors are key drivers as well
  - Current use of PVC (with plasticizer) blood bags may be evaluated for other alternatives
- Polymer price
- Commonly competing polymers depending on the applications
  - PP
  - PE
  - Nylon
  - ABS
  - PS
  - PET
  - PVC

Multi-layer packaging



Plastic additives

- In the Food Contact Material regulation (10/2011 EU), a plastic additive is defined as:
  - “Additive” means a substance which is intentionally added to plastics to achieve a physical or chemical effect during processing of the plastic or in the final material or article; it is intended to be present in the final material or article.
- There is a wide range of plastic additives that can be used in a plastic. It should be noted that although there may be many additives that could be added, they generally only represent a small percentage of the total composition of the polymer
- Common additives include
  - Antioxidants
  - UV stabilizers
  - Colorants
  - Flame retardants
  - Plasticizers
  - Impact resistance
  - Hardeners
  - Antistatic agents

Plastic additives (generally)

High additive content

Polymer type	Possible additives
PVC	Plasticizers, stabilizers
ABS	Impact modifiers, heat stabilizers, colorants, flame retardants
Nylon	Plasticizers, antioxidants, flame retardants
Polycarbonate	Impact modifiers, UV stabilizers, flame retardants

Moderate additive content

Polymer type	Possible additives
HDPE	UV stabilizers, antioxidants, colorants
LDPE	UV stabilizers, antioxidants, colorants
PP	UV stabilizers, antioxidants, colorants, flame retardants
PET	UV stabilizers, antioxidants, colorants

Low/No additive content

Polymer type	Possible additives
Polyethylene	Antioxidants
Polystyrene	

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