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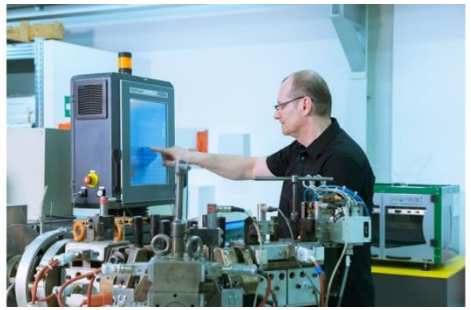


Research on Mechanical Recycling of Bioplastics

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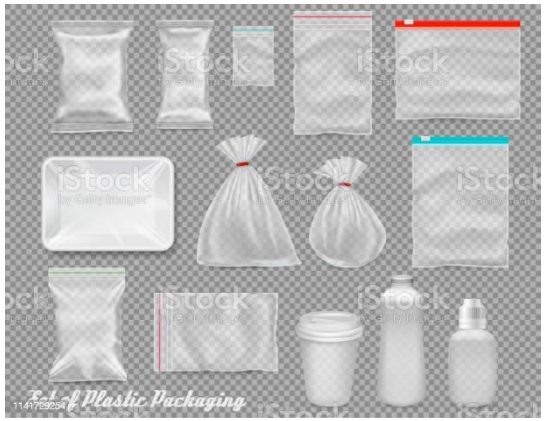
GHENT UNIVERSITY

C-PlaNeT

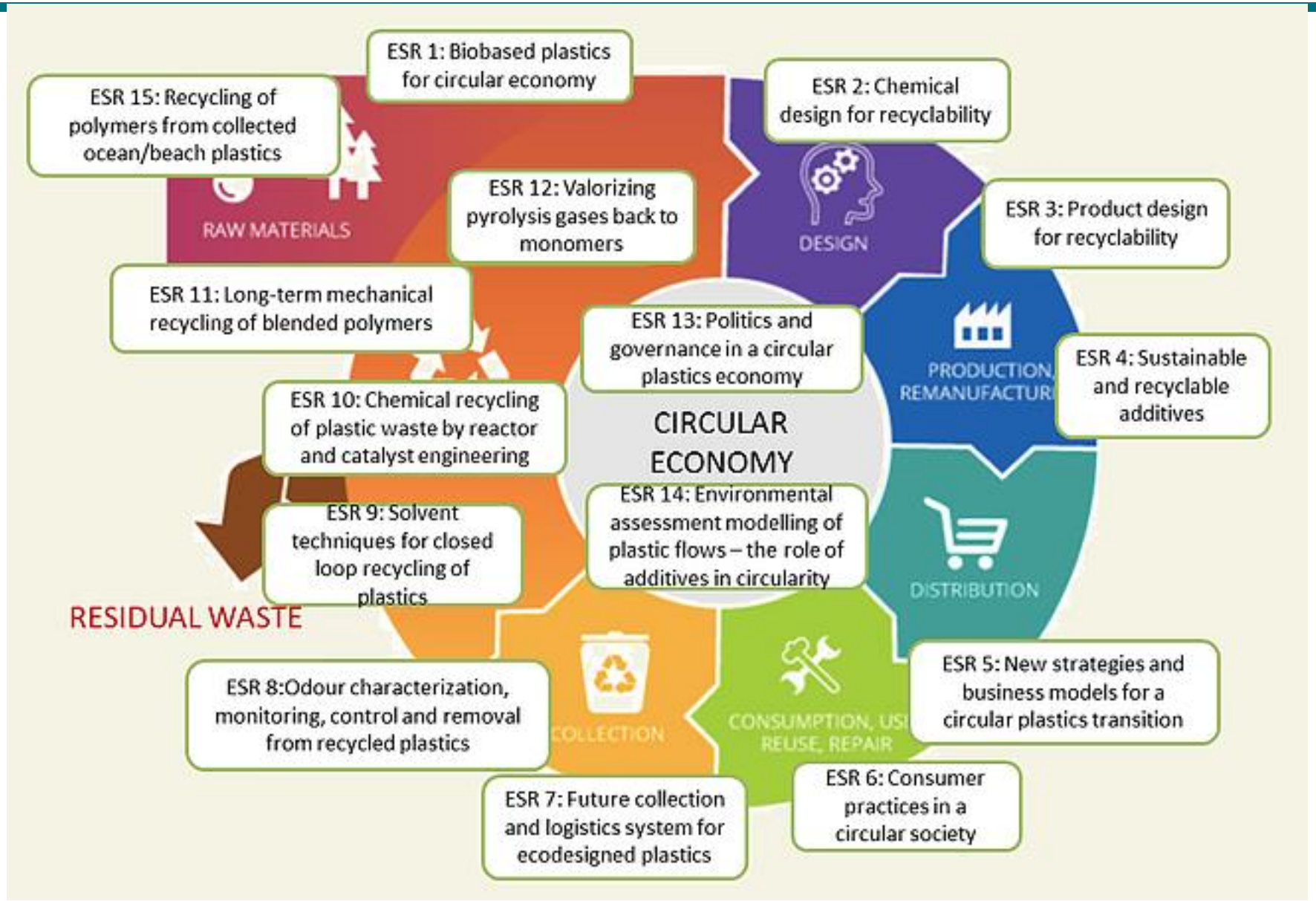
CIRCULAR PLASTICS NETWORK FOR TRAINING

Plastics and Packaging and Pollution



Is this the only way?

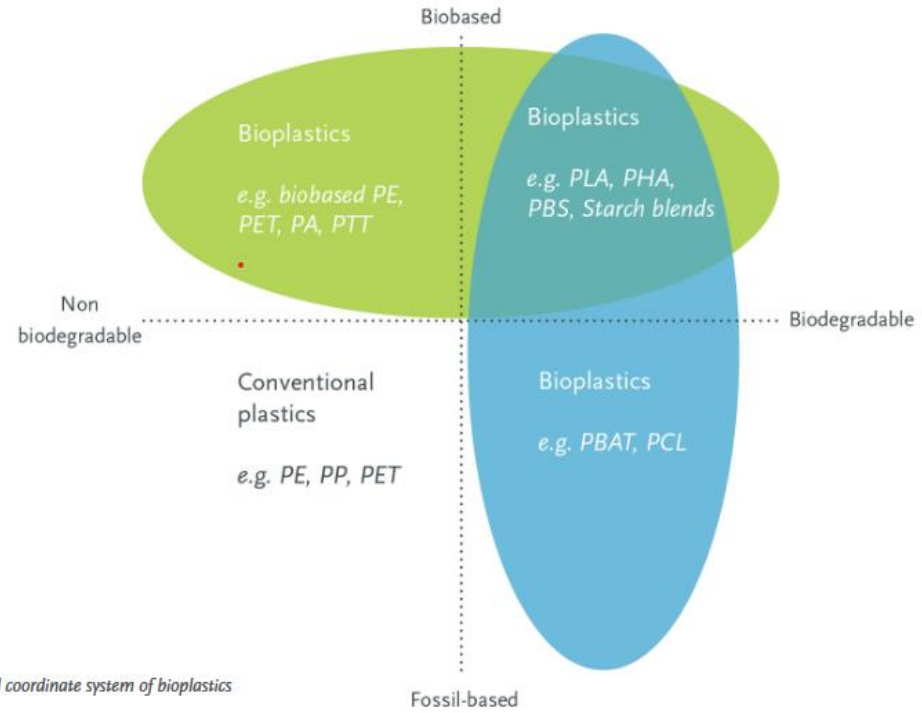
C-PlaNeT


ESR 1: Biobased plastics for circular economy
ESR 2: Chemical design for recyclability
ESR 15: Recycling of polymers from collected ocean/beach plastics
ESR 3: Product design for recyclability
ESR 12: Valorizing pyrolysis gases back to monomers
RAW MATERIALS
DESIGN
ESR 11: Long-term mechanical recycling of blended polymers
ESR 13: Politics and governance in a circular plastics economy
PRODUCTION, REMANUFACTUR
ESR 4: Sustainable and recyclable additives
ESR 10: Chemical recycling of plastic waste by reactor and catalyst engineering
CIRCULAR ECONOMY
ESR 14: Environmental assessment modelling of plastic flows – the role of additives in circularity
ESR 9: Solvent techniques for closed loop recycling of plastics
DISTRIBUTION
RESIDUAL WASTE
ESR 5: New strategies and business models for a circular plastics transition
ESR 8:Odour characterization, monitoring, control and removal from recycled plastics
COLLECTION
CONSUMPTION, USI REUSE, REPAIR
ESR 6: Consumer practices in a circular society
ESR 7: Future collection and logistics system for ecodesigned plastics

Biopolymers

What is a biopolymer?

- A polymer material that fulfills at least one of the following properties:
  - Consists (partly) of bio-based (renewable) raw materials
  - Is in some way biodegradable [3]



Graph: Material coordinate system of bioplastics

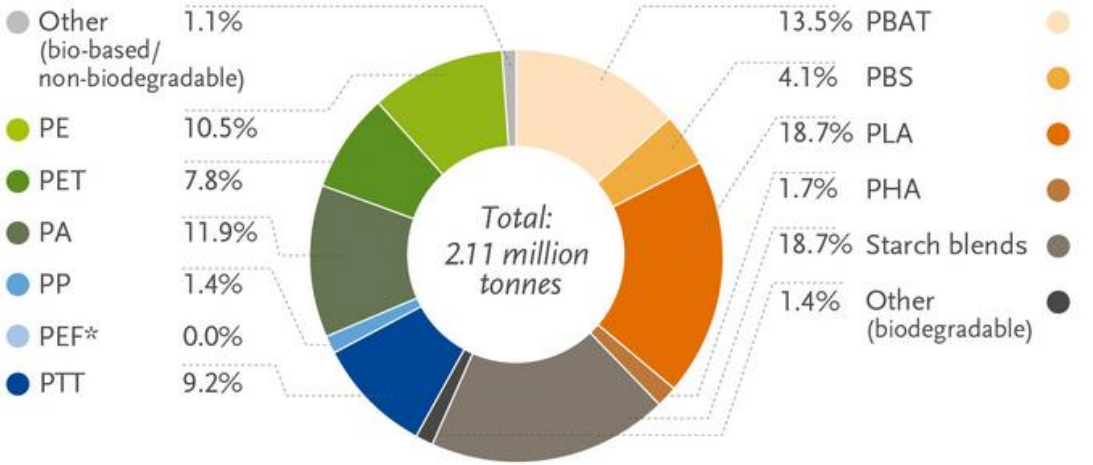
Fig.1:European Bioplastics: What are bioplastics?, Fact Sheet

Some more definitions

- Degradable
  - applies to polymers or plastics that disintegrate by a number of processes, including physical disintegration, chemical degradation, and biodegradation [6].
- Biodegradable
  - A material is considered biodegradable if all its organic components generally and regardless of any time factor are subject to primary and final degradation by biological activity [3].
- Compostable
  - A material or materials mix and parts produced from it is considered compostable, when, under defined conditions in a composting system, it is entirely transformed into CO_2 , H_2O, CH_4, and biomass within a specified length of time, i.e., mostly during a composting cycle ranging from a few weeks to months [3].

Bioplastics production

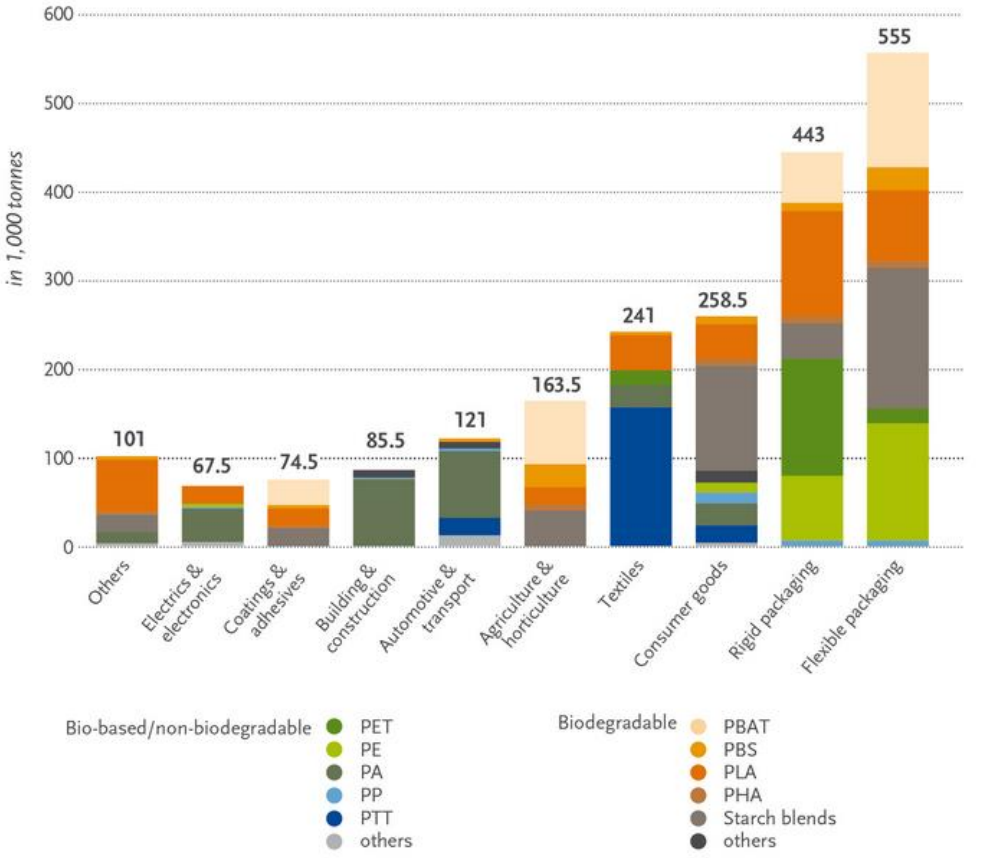
Global production capacities of bioplastics 2020 (by material type)



*PEF is currently in development and predicted to be available in commercial scale in 2023.

Source: European Bioplastics, nova-Institute (2020)
More information: ***www.european-bioplastics.org/market*** *and* ***www.bio-based.eu/markets***

Global production capacities of bioplastics 2020 (by market segment)



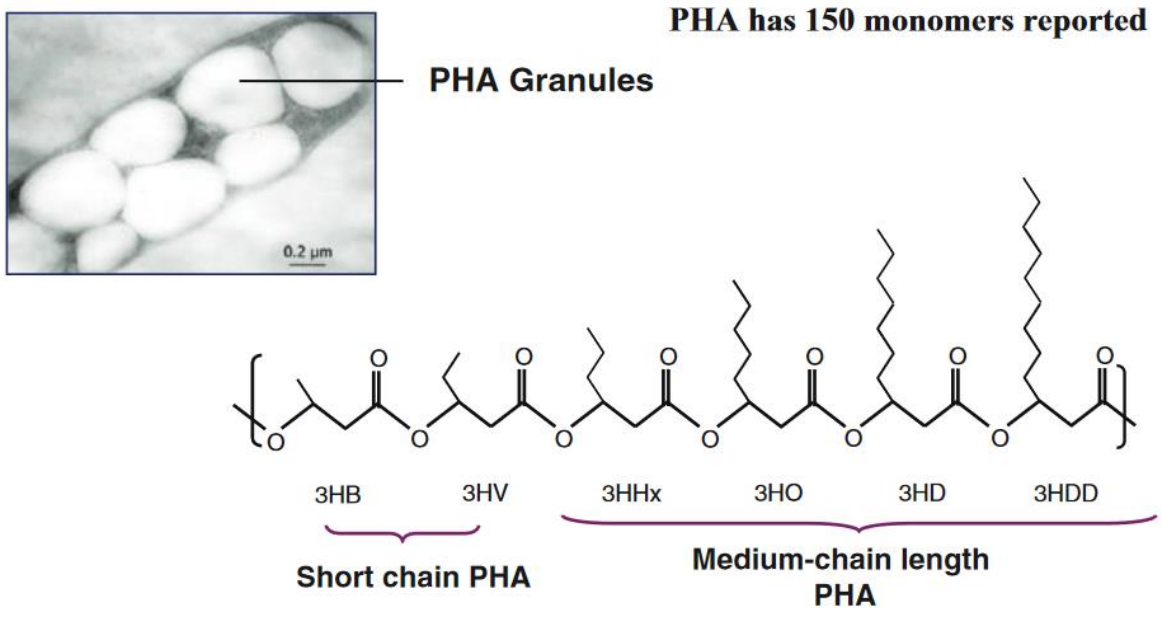
Source: European Bioplastics, nova-Institute (2020). More information: ***www.european-bioplastics.org/market*** *and* ***www.bio-based.eu/markets***

Polyhydroxyalkanoates (PHAs)

What are PHAs?

- Among these biopolymers, only polyhydroxyalkanoates (PHAs) are produced in vivo, all others are polymerized by chemical reactions [2].
- Polyesters produced by a variety of microorganisms in different conditions.
- They are accumulated as intracellular storage granules.
- Thermoplastic, biodegradable, biocompatible, nontoxic, good barrier properties [12].
- The general structure:
- –O–CHR–(CH2)m–CO– [9]

- Generally divided into:
  - Short chain length:
    - 3-5 C atoms eg: PHB, PHV
  - Medium chain length:
    - 6–14 C atoms eg: PHHx
  - Long chain length:
    - >14 C atoms eg:PHBHHx [12]



Polyhydroxybutyrate (PHB)

PHB- Polyhydroxybutyrates

- –O–CH(CH_3)–(CH2)–CO–
- Linear isotactic structure and highly crystalline(60-70%)[2]

- Properties
  - Water insoluble
  - relatively resistant to hydrolytic degradation
  - P (3HB) is optically pure and possesses piezo electricity
  - Tensile strength of 30–40 MPa, and elongation at break of a few percent.
  - Tm of P3HB is high, near 177°C [9]

Fig.4: Maurice Lemoigne- the French scientist who extracted P(3HB) from Bacillus megaterium in 1927.

- In terms of molecular weight, melting point, crystallinity and tensile strength, PHB is still equivalent in comparison with a conventional plastic of polypropylene (PP).

- It is even better than PP and PET with respect to oxygen, water vapor, fat and odour barrier properties. Therefore, a development of PHB mechanical properties is necessary to fully exploit its useful attributes for packaging applications [12].

Challenges

- A relatively low thermal decomposition temperature of PH3B is also a problem as well as ageing at room temperature [9].
- The former complicates industrial processing of the polymer,
  - as **thermal degradation occurs** at temperatures close to the melting point,
  - with a decrease in molar mass [2]
- Regarding the mechanical properties,
  - PHB undergoes **progressive embrittlement upon storage.**
  - Soon after molding, PHB exhibits ductile behavior, but when the molded product is stored at room temperature, the material becomes very brittle [2]

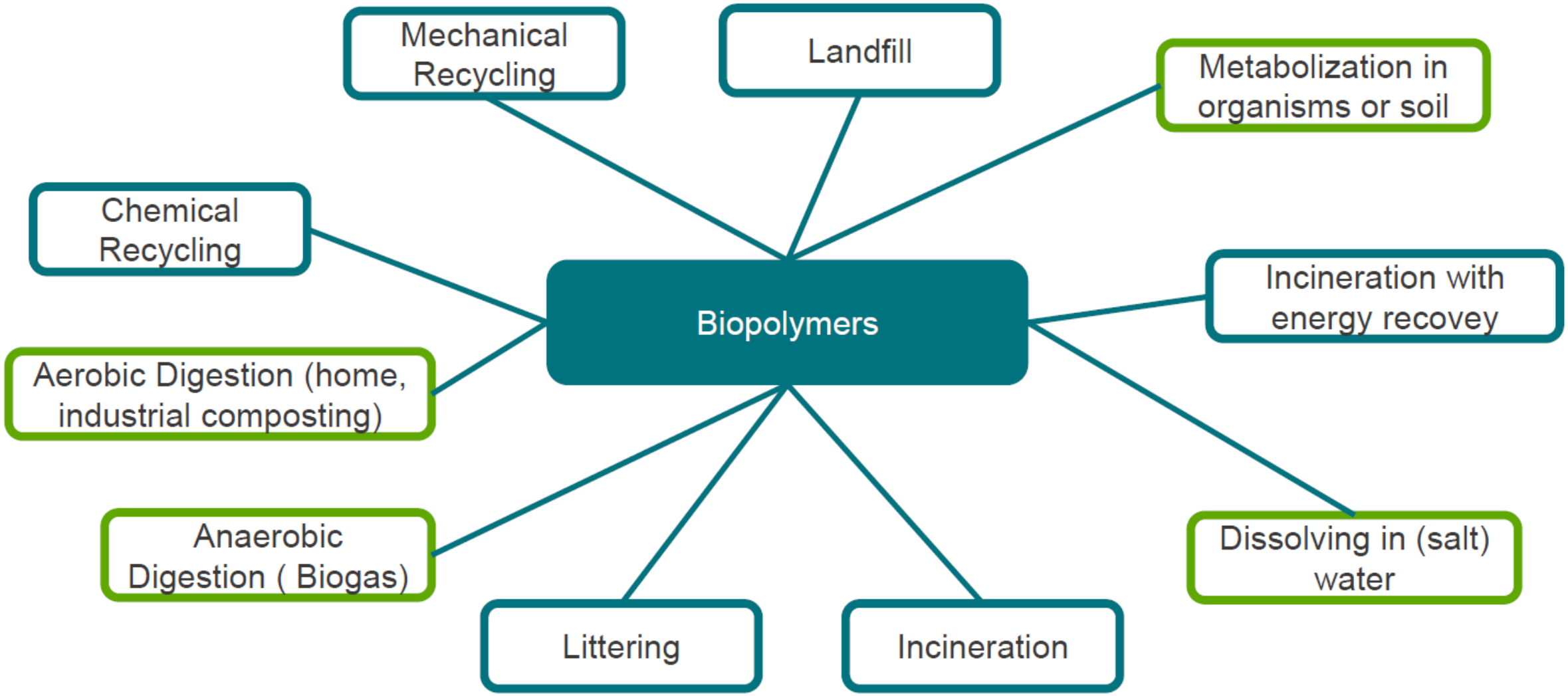
- To overcome these disadvantages, research efforts focused on finding effective nucleating agents and plasticizers to shorten crystallization, to improve flexibility and drawability, and to reduce Tm [9].

Increasing Heat Resistance:

- Heat resistance of bioplastics is insufficient for use as a packaging material for foods undergoing a heat treatment before or after packaging.
- Furthermore a poor heat resistance can also lead to degradation of the polymer during processing [7]
- Adding Additives:
  - plasticizers, chain extenders, nucleating agents, and nanoparticles
- Blends and copolymers
- Incorporation of filler
- Adjustment of processing parameters

End of Life Scenario

End of life options- Biopolymers



Source: Rickert J.; Recycling of Biopolymers (n.m); Life Cycle Engineering research group, TU Braunschweig

Recycling Methods

Fig.7: Image source: packagingeurope.com/fkur-position-paper-bioplastics-circulareconomy/

Objectives

- Mechanical Recycling:
  - In contrast to energy recovery, chemical recycling and composting, mechanical recycling allows for preserving the polymer structure and the material value in terms of feedstock and polymerization energy. So it is crucial to ensure the sustainability of biobased plastics in the long term [10].

- **Objective of Research:**
  - Further development of mechanical recycling of bioplastic packaging,
    - Additivation
    - Stabilisation
    - Food grade applicability
    - Investigation on number of reprocessing cycles
  - Improve the current bioplastic packaging products (with focus on PHAs).

Biopolymer Recycling Overview

- Scarce experience in the field of thermoplastics biopolymers
- Causality dilemma:
  - Industrial scale recycling requires significant investments
  - Investment will only come if biopolymer commercial volumes and sales increase sufficiently
  - Uncertain recycling possibilities hinder demand for bioplastics and thus, prevent high quantity waste streams
- To be expected: Similar behavior (and problems) to conventional thermoplastics.
- Biopolymer drop-ins are being recycled together with fossil-based counterparts.
- Cross-contamination of petrochemical polymers with biopolymers (e.g. PET with PLA) is problematic, but is only a problem of sorting technology
- Development of recycling processes for post-consumer waste is ongoing
- Current status: No industrial recycling streams for biopolymers [13].

Summary

- Packaging is necessary but to be made from bioplastics.
- PHAs are a good choice.
- Mechanical recycling to be developed further.

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Thank You for your attention!