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PrimeView
Sustainable polymers

Sustainable polymers are materials derived from renewable, recycled and waste carbon sources, which can be recycled or composted at the end of their life cycle, with minimal environmental impact. Their adoption requires design to maintain sustainability throughout the production process without increasing costs.

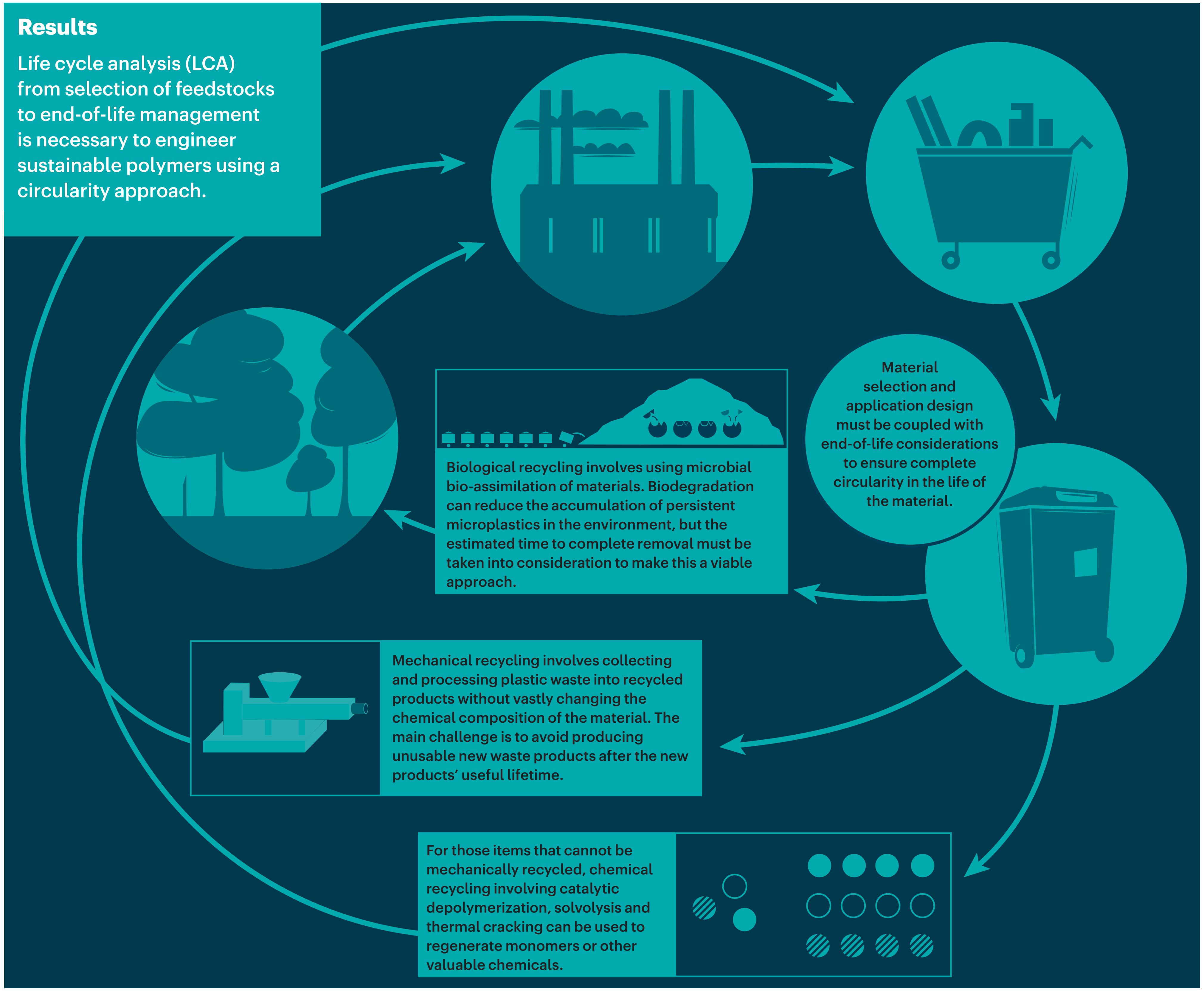
Experimentation

The development of sustainable polymers begins with the extraction of monomers from natural feedstocks, including biomass and waste residues. Renewable polymers can include those that have a similar chemical structure to their fossil fuel analogues (known as drop-in polymers) as well as new bio-based polymers with no fossil fuel analogues. Examples of bio-based polymers like bio-polyethylene can be obtained from agricultural resources such as crops, algae and cooking oil. Bio-based monomers are extracted from feedstock by transformation and purification ideally using sustainable methods of extraction. The transformation of bio-based monomers into sustainable polymers is performed using chemical, enzymatic or microbial polymerization, with step-growth polymerization and chain-growth polymerization being the more commonly used polymerization processes.

● Sustainable polymers are relatively new to the consumer market, and attention must be paid to ensure sustainability, both in their production and use.

Limitations and optimizations

Challenges limiting the adoption of sustainable polymers include constraints at the end of the product's life and limitations in scaling up of manufacturing and associated costs. The cost, energy efficiency and potential for contamination of bio-based plastics remain major limitations in recycling, and the biodegradation and composting of materials requires specific conditions and additional energy. Scaling synthesis of sustainable polymers beyond the laboratory requires adjustment to existing downstream processing systems and development of new synthesis platforms.



Reproducibility and data deposition

The composition of the feedstocks is influenced by the growing season, collection and storage methods, as well as transportation and sorting. Standard processing and characterization methods should be adopted that account for different compositions of starting materials and impacts these have on extraction. The deposition and sharing of data regarding characterization conditions and intuitive data display is crucial to make data comparable between groups and experiments. Data reporting should include beginning and end-of-life information and the bio-based carbon fraction of the materials.

Applications

Sustainable polymers are currently being used in commercial applications, including biodegradable/compostable products such as shopping bags and cutlery, bio-based bottles, composites used in vehicles, products designed from recycled plastics and bio-based coatings and adhesives. Some emerging commercial applications are not yet commonly used, including bio-based transparent wood, paper-based microelectronics and energy harvesting textiles and electronics based on silk and carbon nanotubes. Properties and economic costs remain major bottlenecks for the commercial adoption of sustainable polymers, although work is being done to optimize sustainability across the material life cycle.

Outlook

Sugars, lipids and proteins are commonly used feedstocks but are limited in applicability to demanding conditions. Sources from lignin-based aromatics will allow expansion of sustainable polymers in high-temperature applications. Global legislative regulations and public awareness of sustainability will promote and accelerate the adoption of sustainable polymers.

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