Introduction to the BOTTLE Consortium

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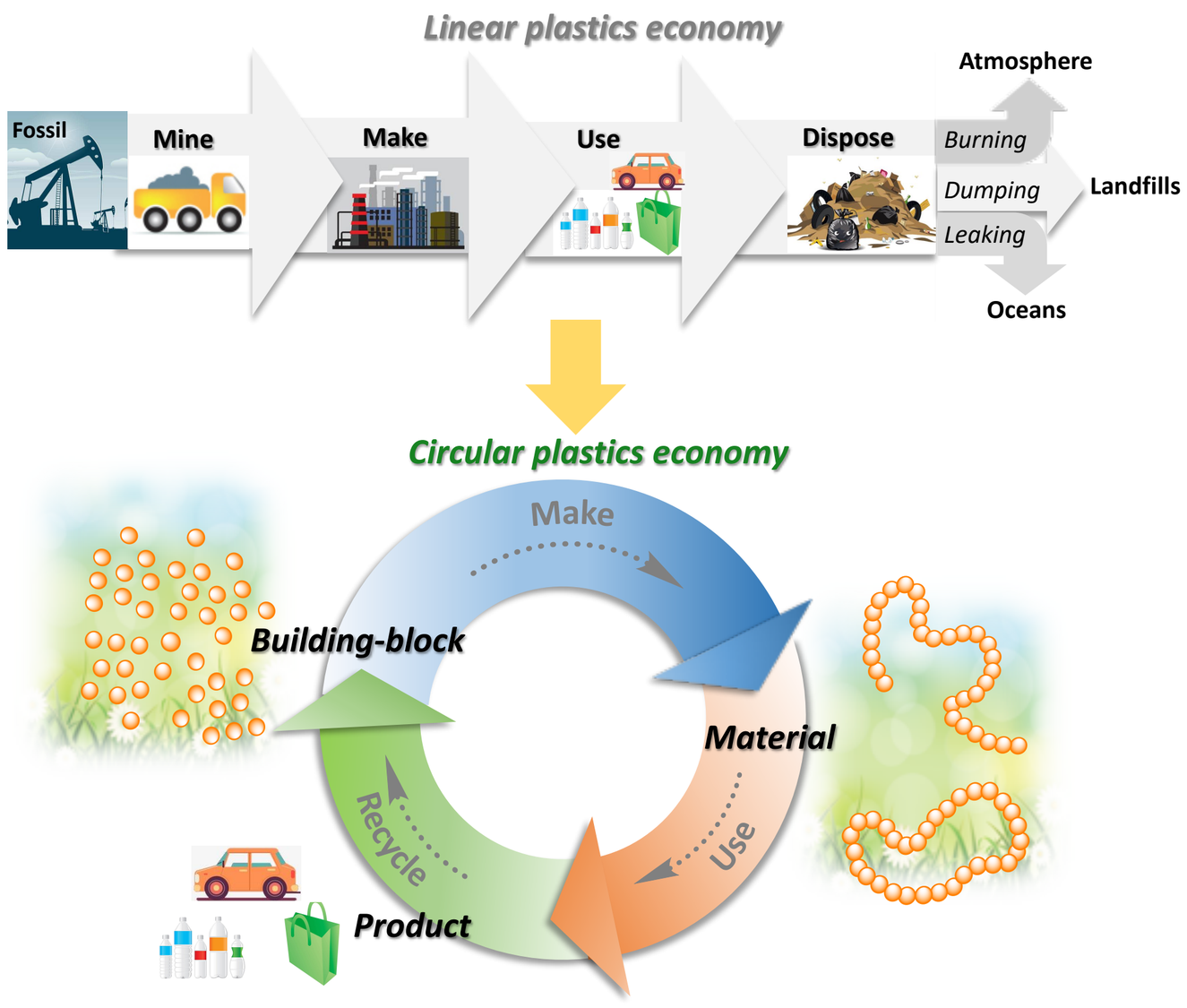
Definitions

BOTTLE: Bio-Optimized Technologies for keeping Thermoplastics out of the Landfill and Environment

Plastics upcycling: the creation of a more valuable product from discarded plastic, which will incentivize waste plastics reclamation

Vision and mission

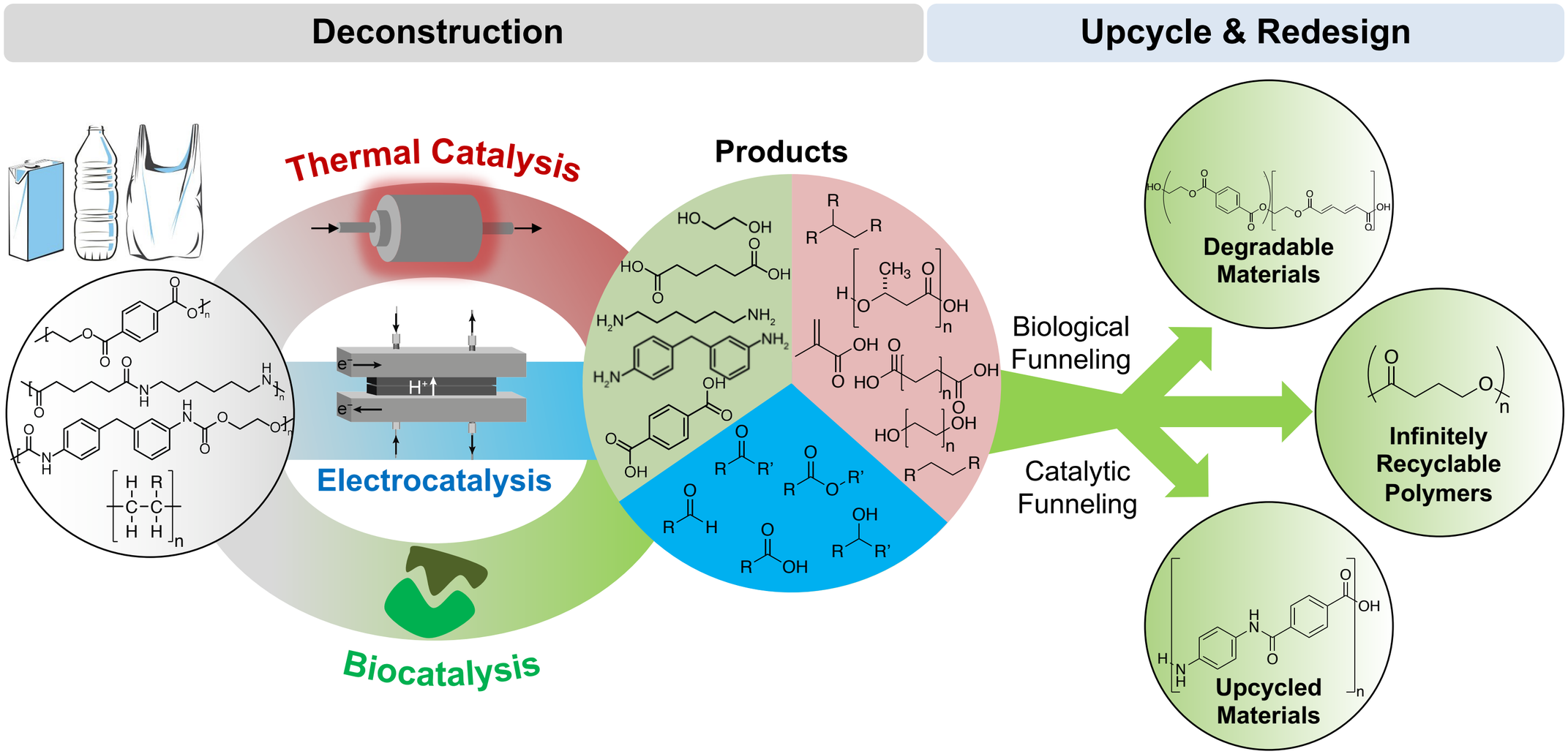
The **vision** for **BOTTLE** is to deliver technologies that will incentivize reclamation of waste plastics to enable a circular plastics economy



The **BOTTLE mission** is to develop robust processes to upcycle waste plastics and develop new plastics that are recyclable-by-design

Goals

- Develop **selective, scalable processes** to deconstruct and upcycle plastics that are discarded in large quantities today including PE, PP, PS, PET, PA, PU
- Design new chemistries and associated processes for direct chemical recycling of future plastics and composites that are recyclable-by-design
- Work with industry to catalyze a new upcycling paradigm for plastics
- Leverage DOE investments in catalysis, materials, modeling, and analysis



Metrics and members

Energy:

- **≥50% energy savings** relative to virgin material production

Carbon:

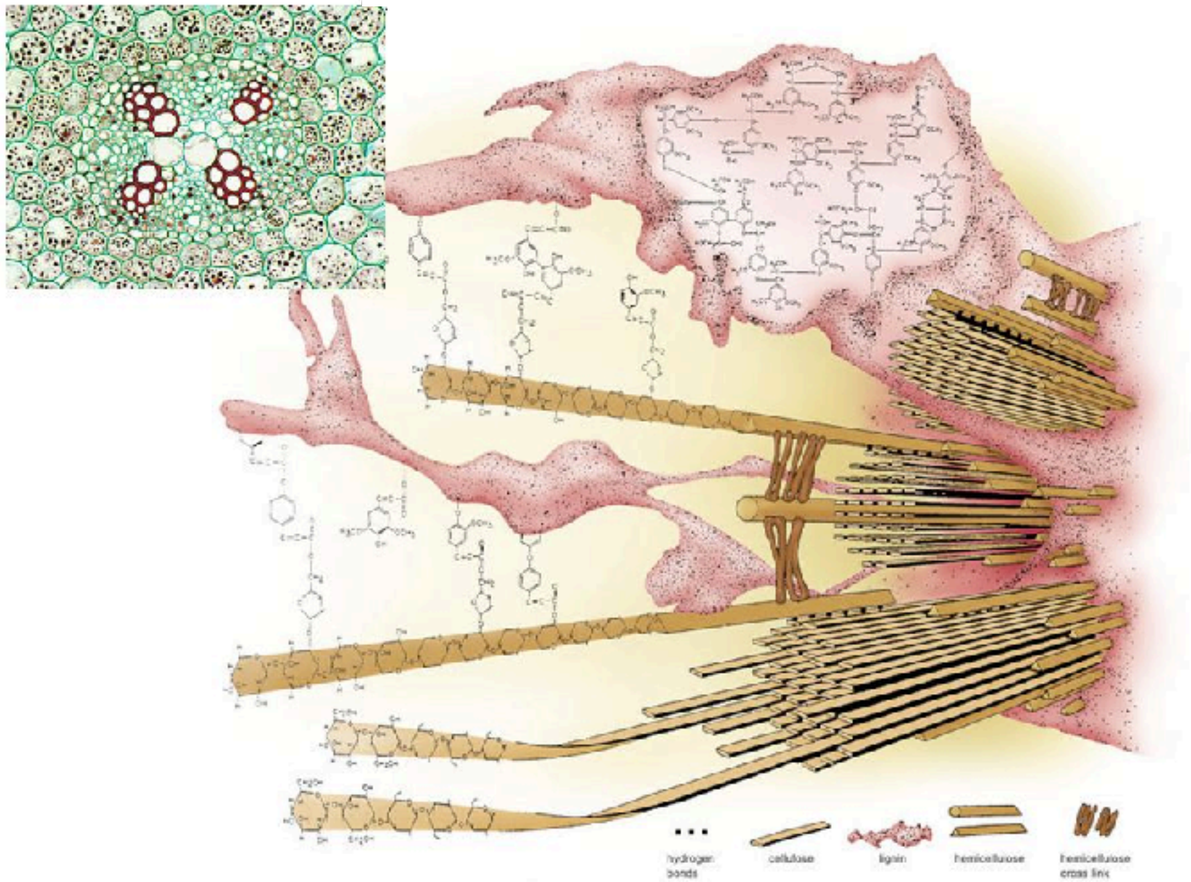
- **≥75% carbon utilization** from waste plastics

Economics:

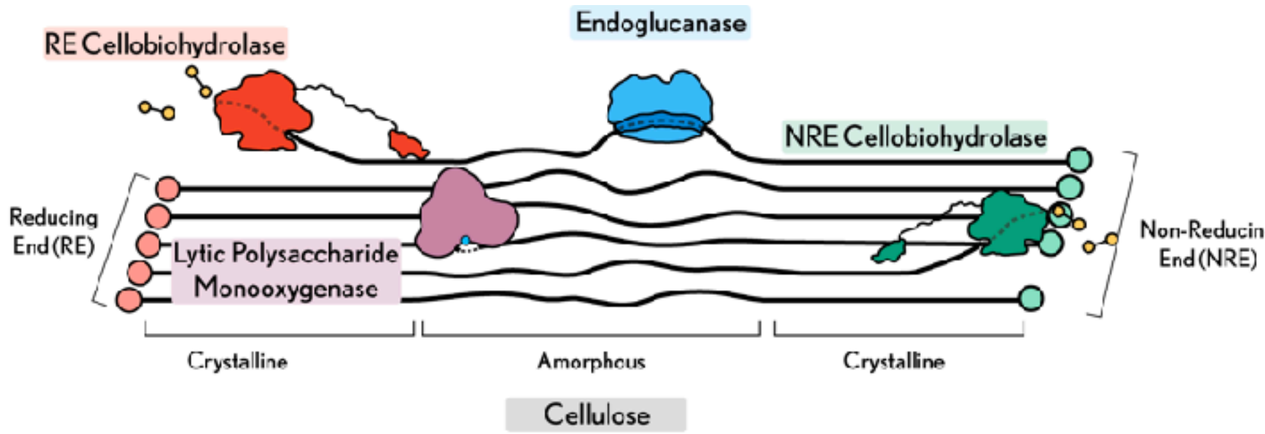
- **≥ 2x economic incentive** above price of reclaimed materials

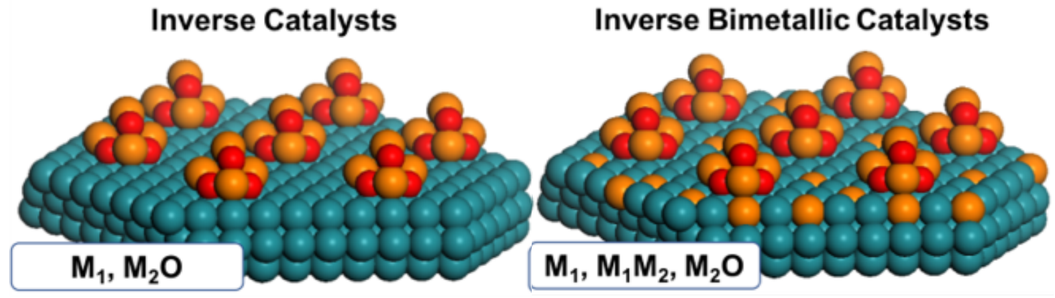
A brief aside to biomass conversion…

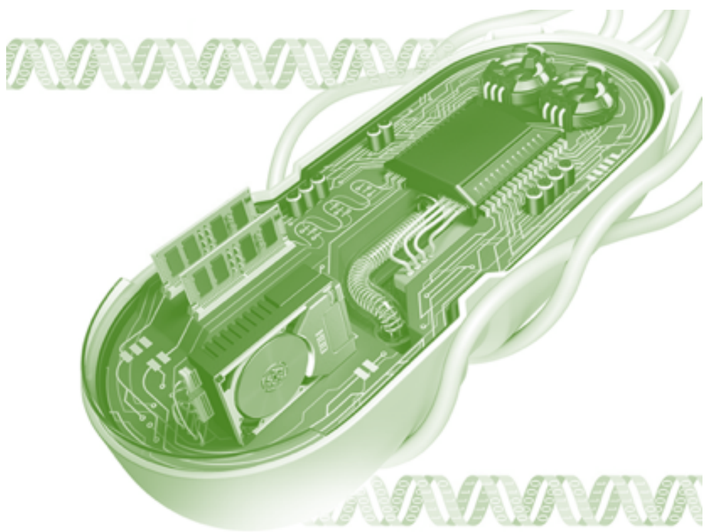
Images from: Bidlack 1993, Schutyser 2015, Vorotnikov 2019



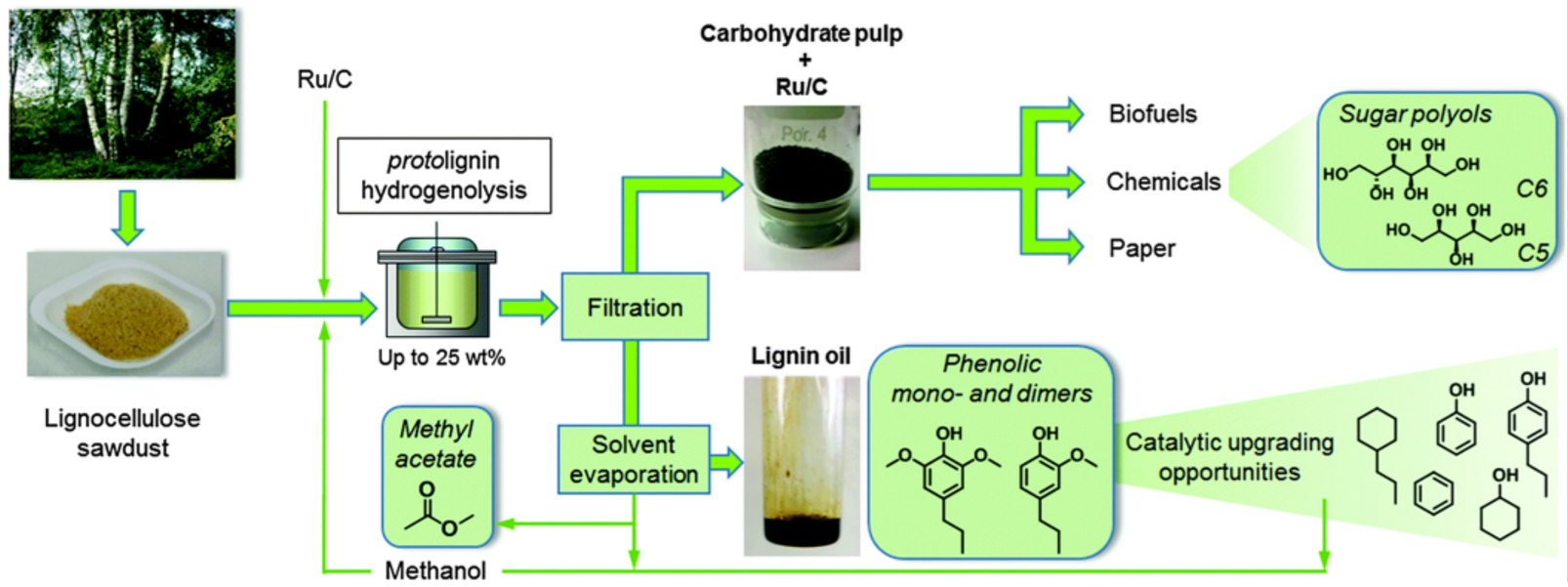
Biological and chemical catalysis



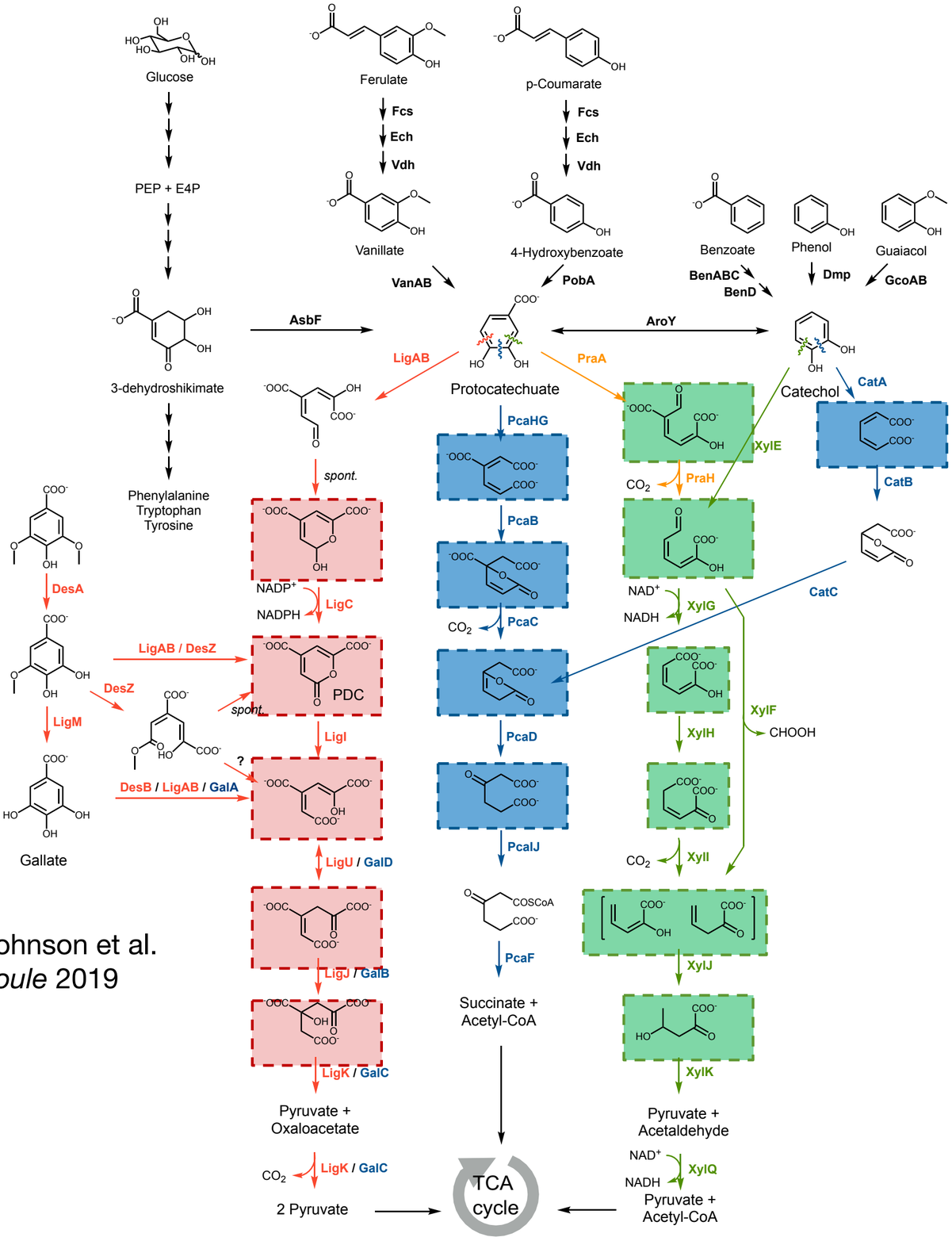




Synthetic biology



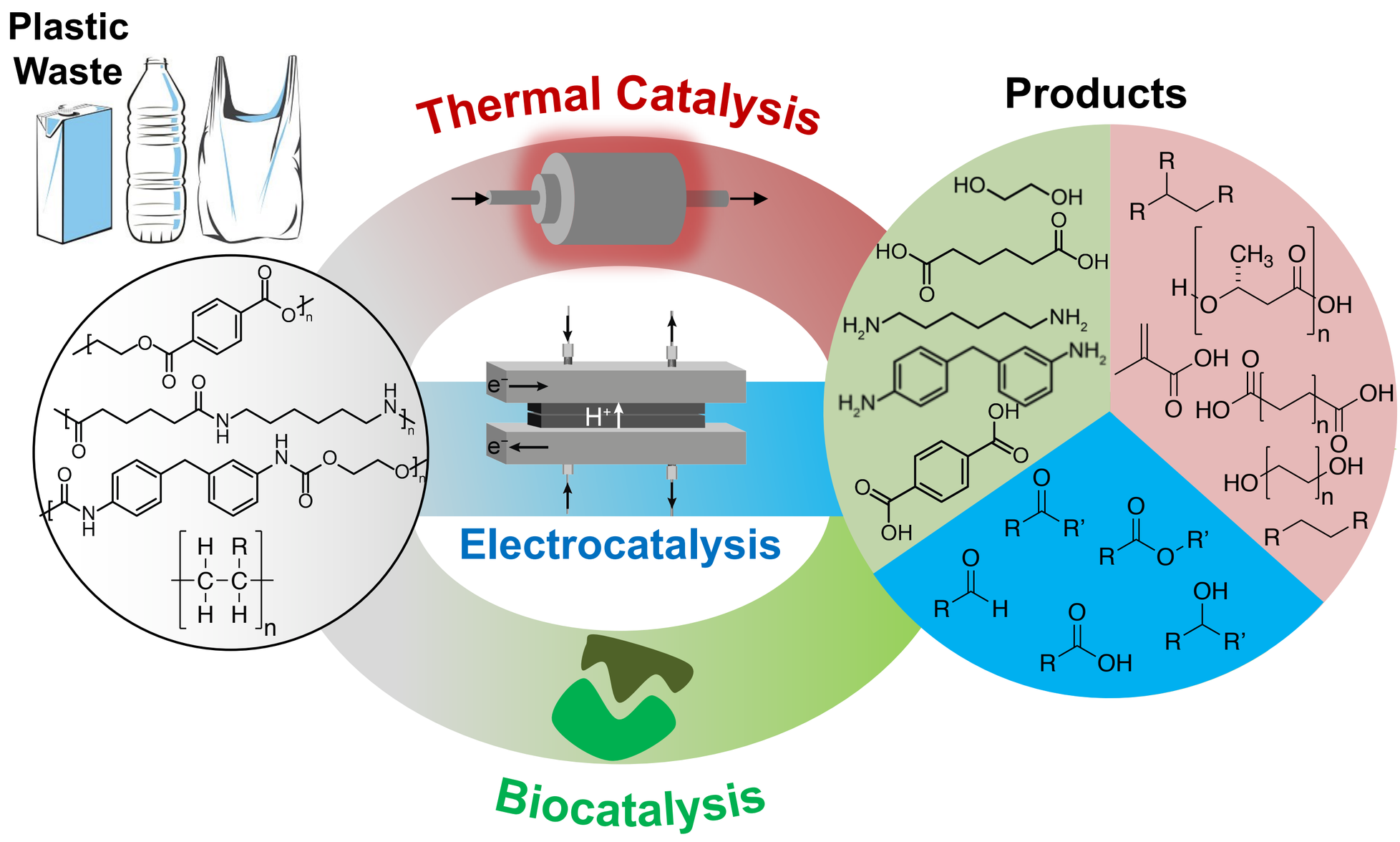
Fractionation, catalysis, process design



Johnson et al.
Joule 2019

Design
Recycle – Reuse – Remanufacture
Reliability
(D R^n R)

The bioeconomy can also let us rethink plastics design…



Plastics deconstruction

Expanding the known collection of PET-degrading enzymes…

Obtain sequences from database

↓

Obtain optimum temperature data for sequences

↓

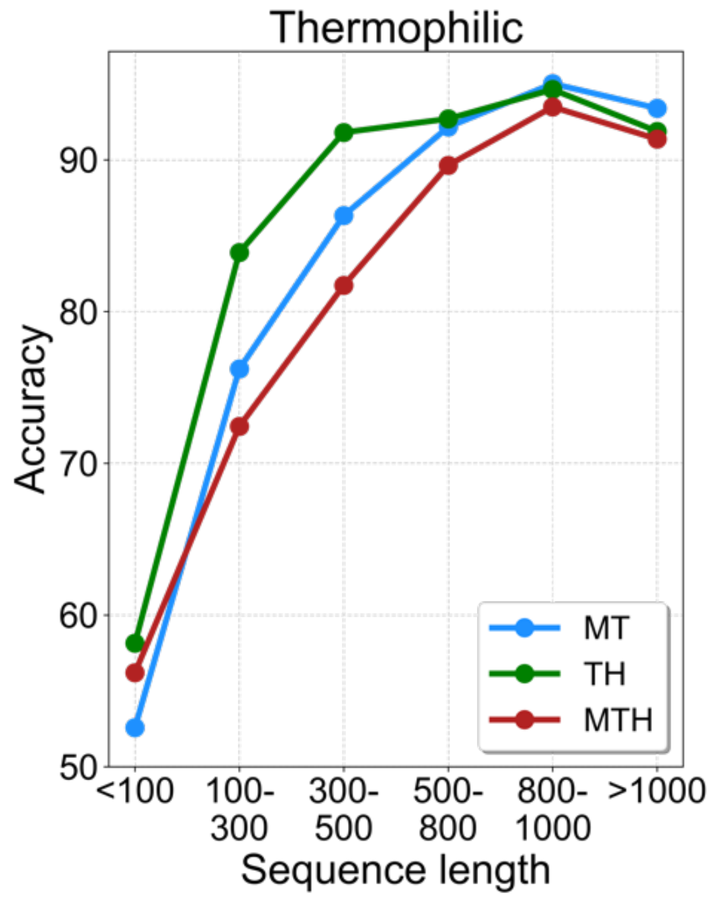
HMM search for potential PETases

↓

Retain Hyperthermophi -lic hits

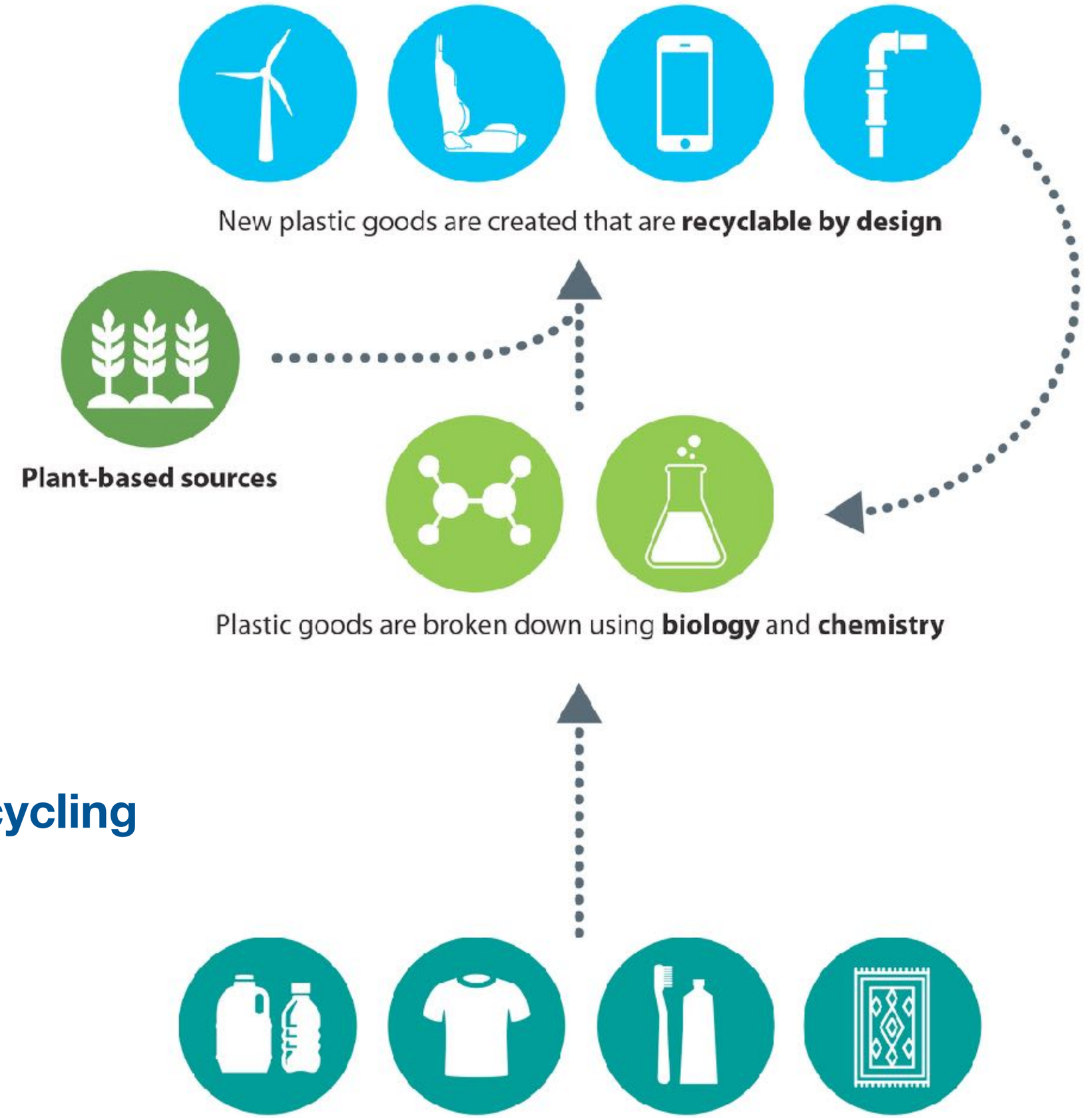
↓

Apply machine learning (ensemble1000)

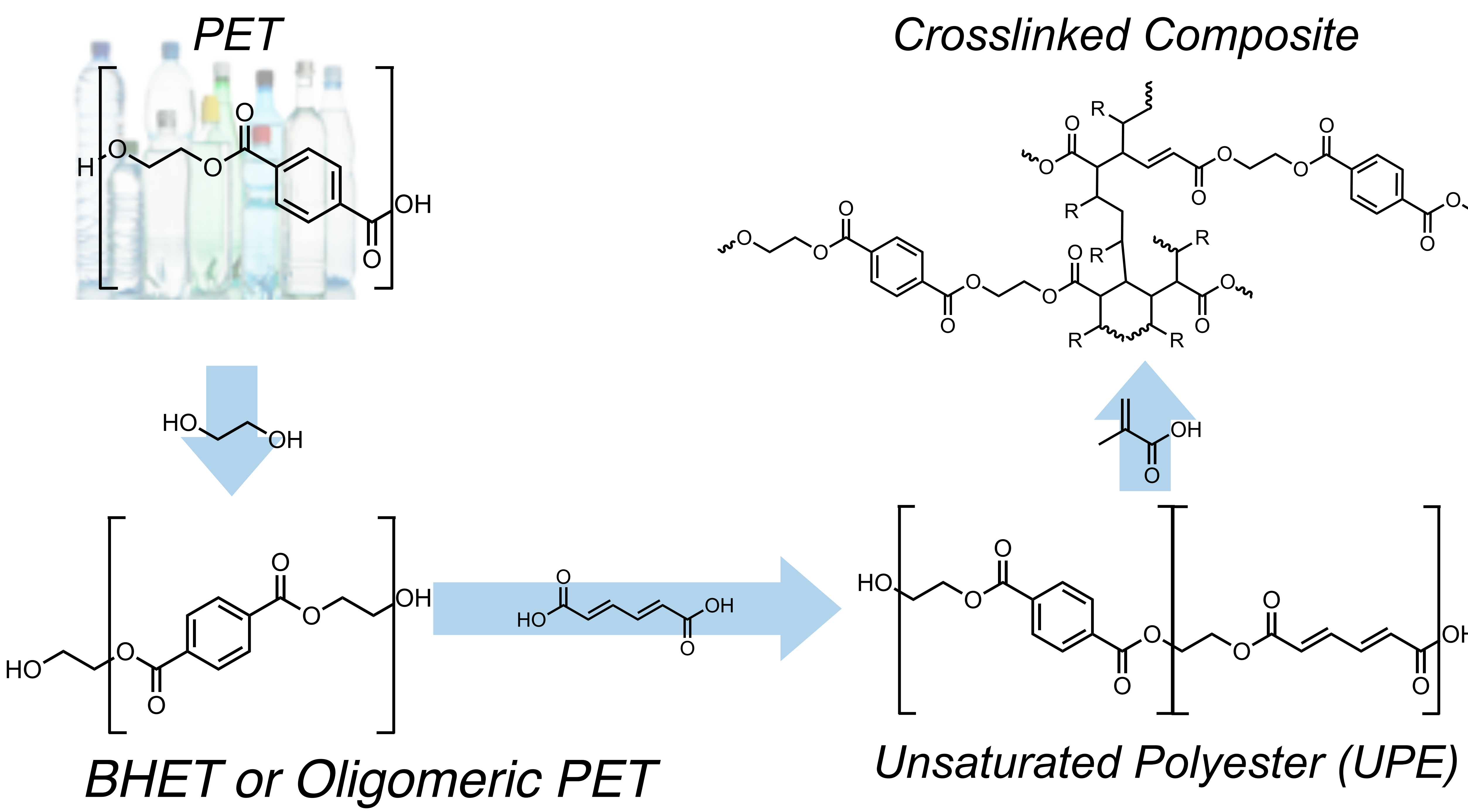


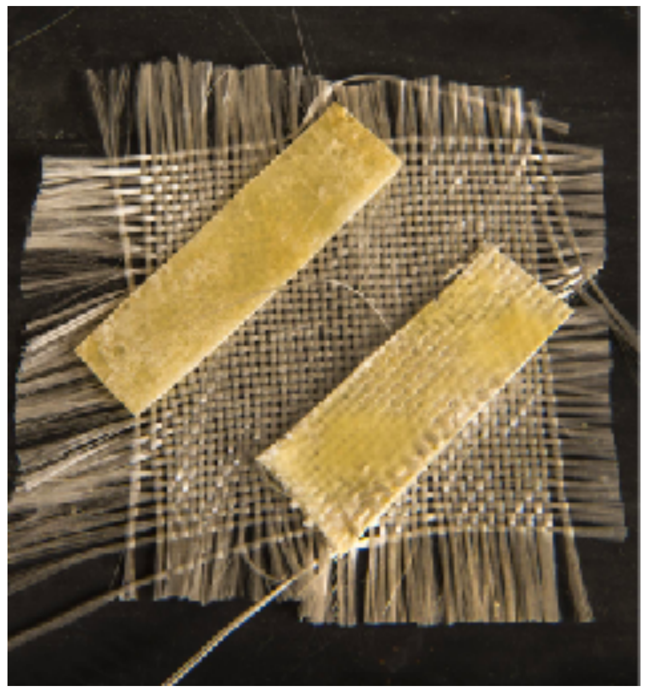
Erickson, Gado, et al. in preparation

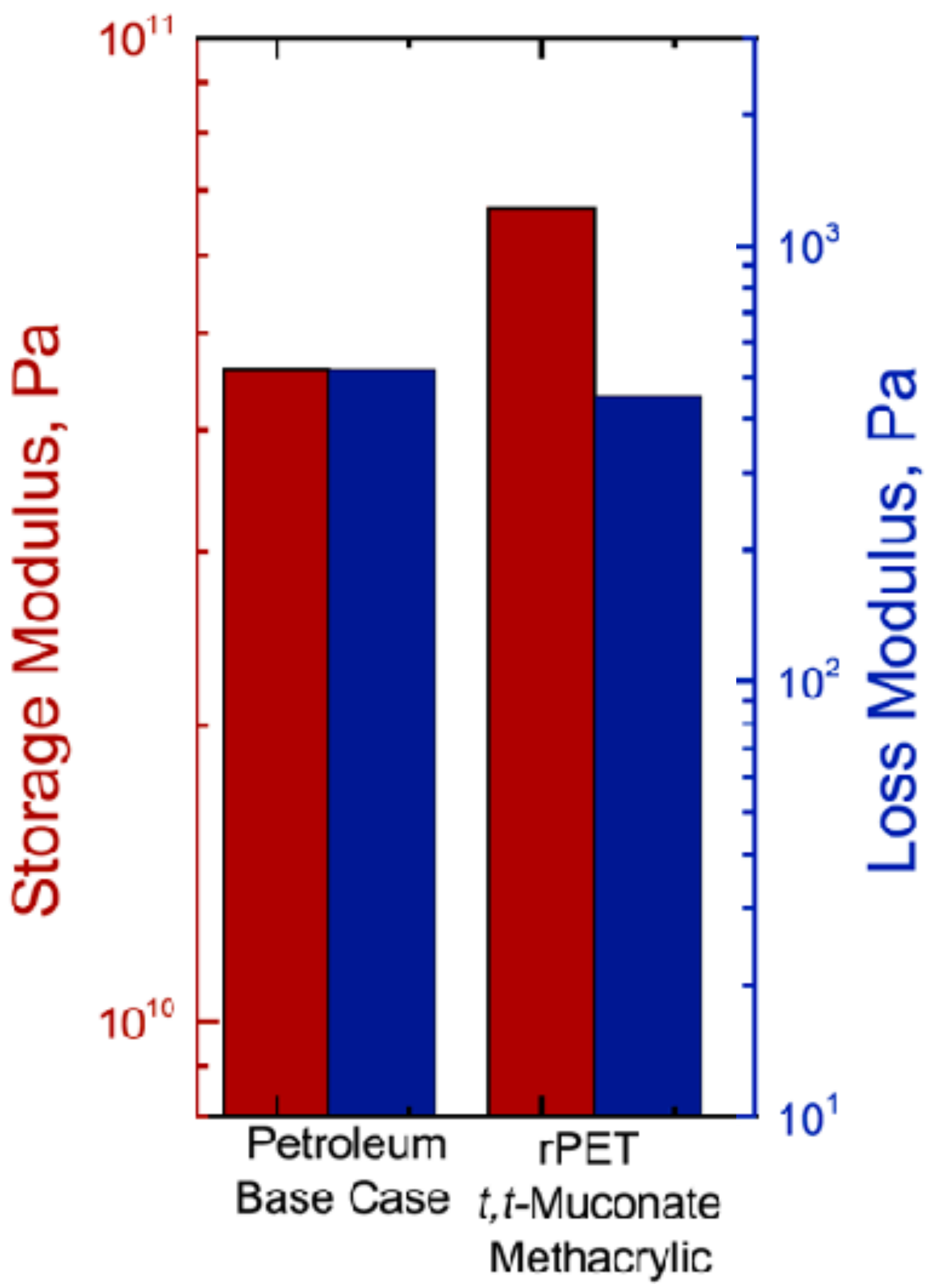
Towards **plastics upcycling**



Can we make higher-value materials from reclaimed PET?

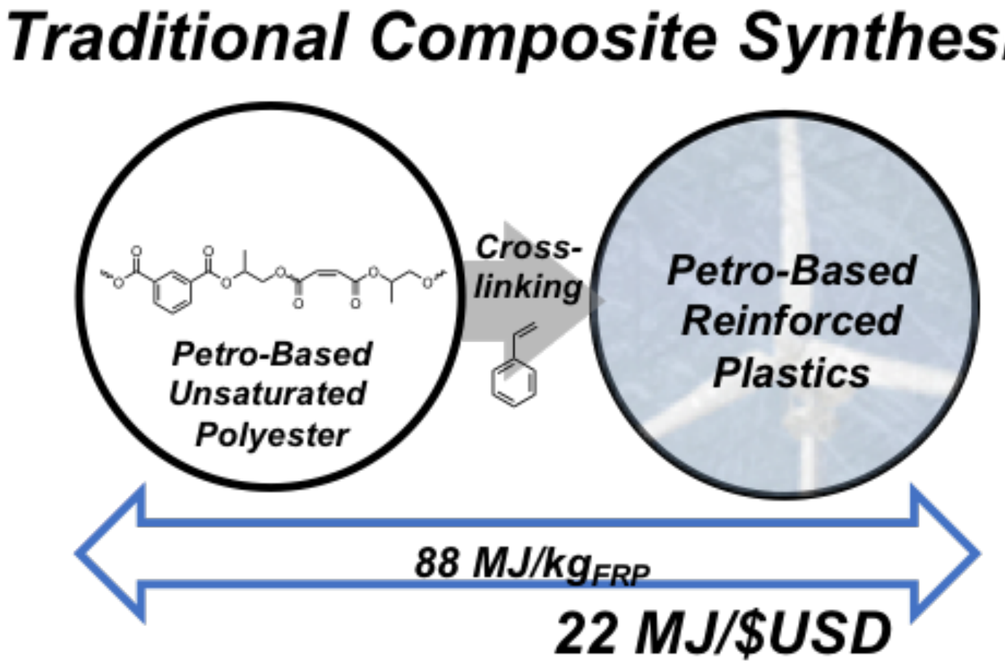






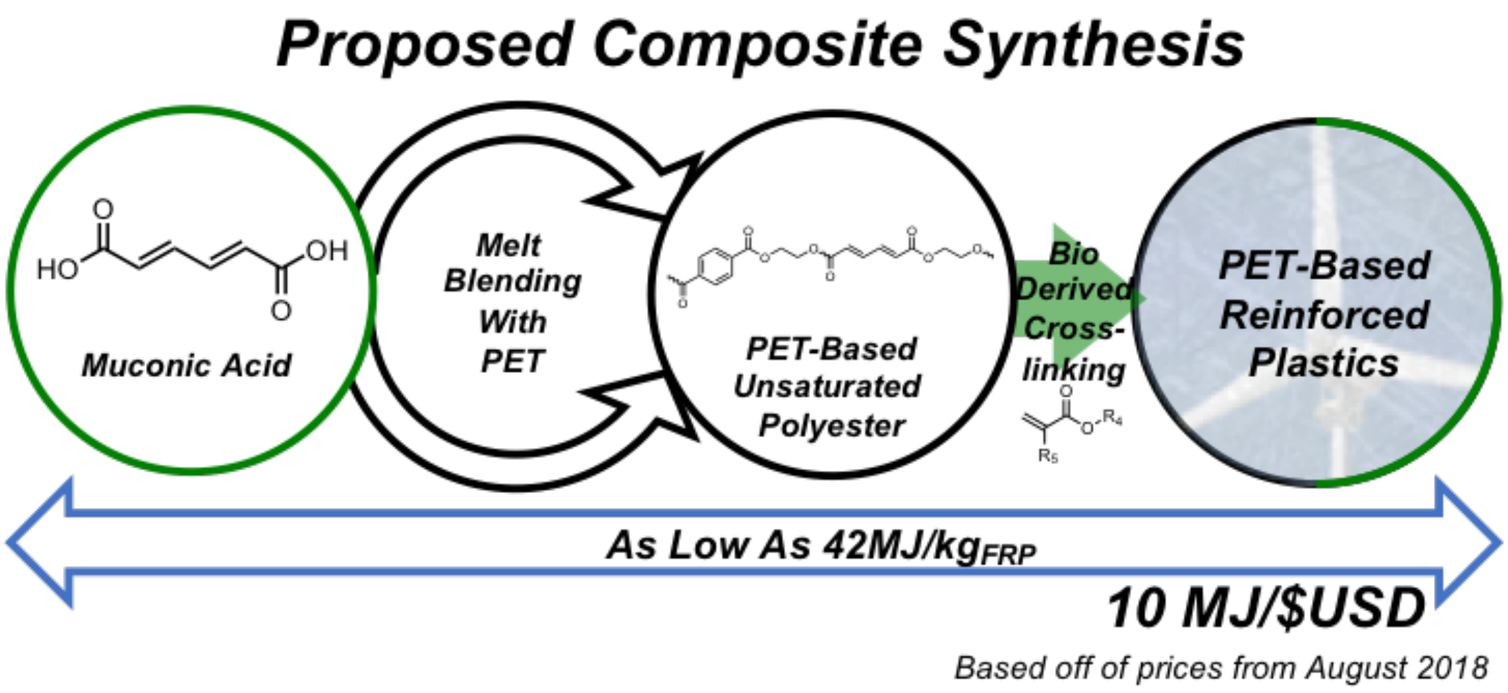
Rorrer *et al. Joule* 2019

Proposed upcycling approach is sustainable and economical



Relative to standard composites manufacturing, rPET + bio-based monomers enable:

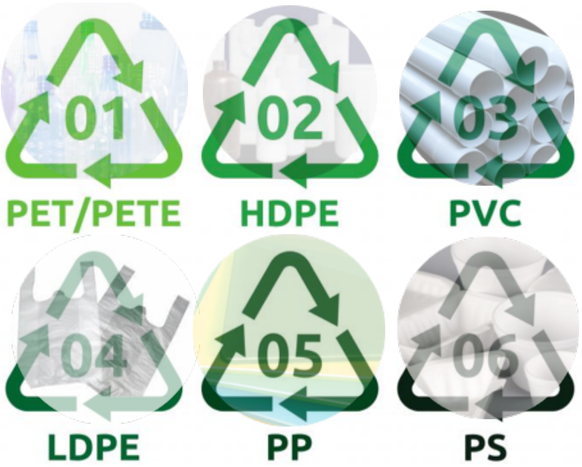
- 57% reduction in supply chain energy,
- 40% GHG emissions reduction
- ~5x value to rPET

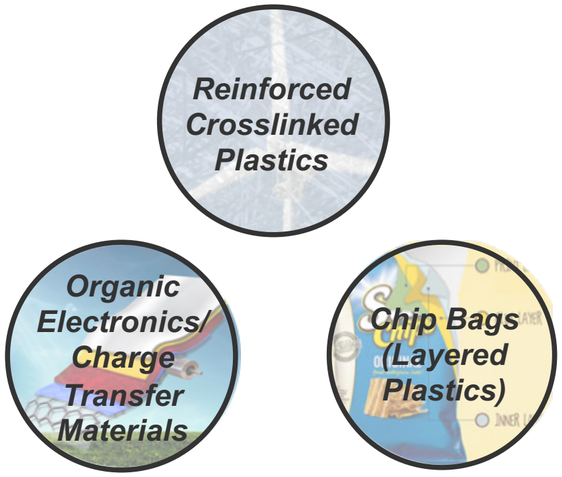


Rorrer *et al. Joule* 2019

Design of new plastics for **degradability**

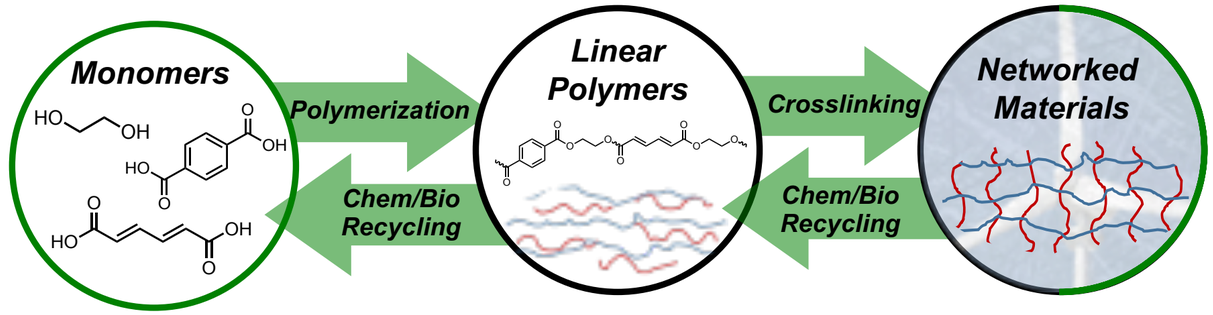
Upcycling Existing Plastics





Opportunities to combine biological and catalytic transformations for efficient deconstruction and upcycling

Recyclable-by-design

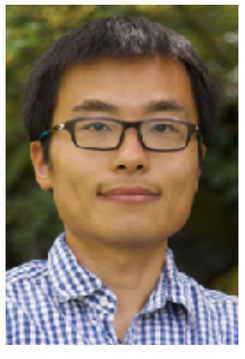


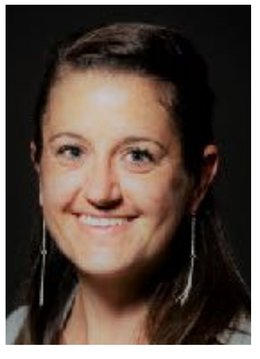
Opportunities:

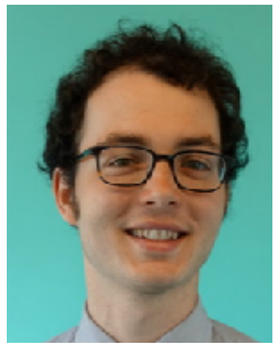
- New material formulations and designs with new building blocks
- Co-design of materials performance and end-of-life recycling processes

Development of biological and chemical recycling technologies for existing plastics will work likely even more effectively with recyclable-by-design plastics

Beckham, Ellis, McGeehan, Rorrer, Wierckx, in preparation







Acknowledgements

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