Polymer/Plastics Recycling:

Challenges and Opportunities

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changing the way we recycle
U.S. DEPARTMENT OF ENERGY

BOTTLE: Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment

May 15, 2023
@URI: Plastics

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Transforming ENERGY
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DOE EERE Laboratory
Golden, Colorado

Challenges in Plastic(s) Circularity

Problem

- Nearly **1 Trillion Pounds** of Polymers Manufactured Annually
- Polymers are **easily tailored** for performance in specific applications
  - **Chemical composition, Molecular size and shape, Additives**
- Macromolecules of dissimilar structure **separate** on the molecular level

Circularity: Collect, Recovery and Recycle

- **Mechanical** Recycling
- Selective **Dissolution** and Purification
- **Deconstruction** and Reconstruction or Upcycling

Innovation Required!

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What about more challenging materials?
--Textiles, Composites, Tires?

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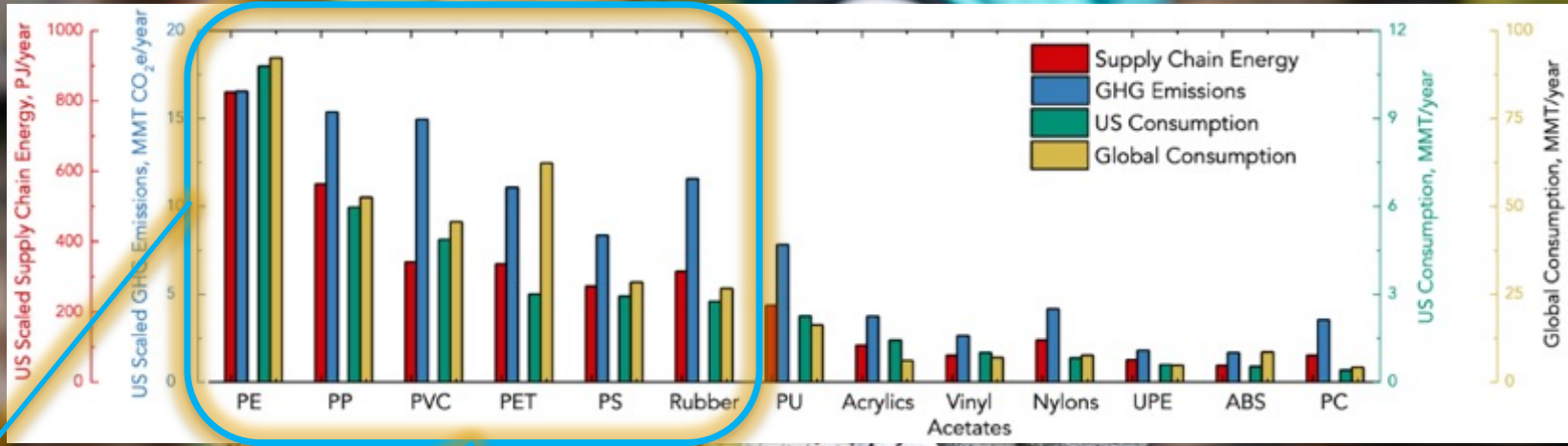
Plastic production accounts for 6% of fossil fuel consumption (20% by 2050)[1]

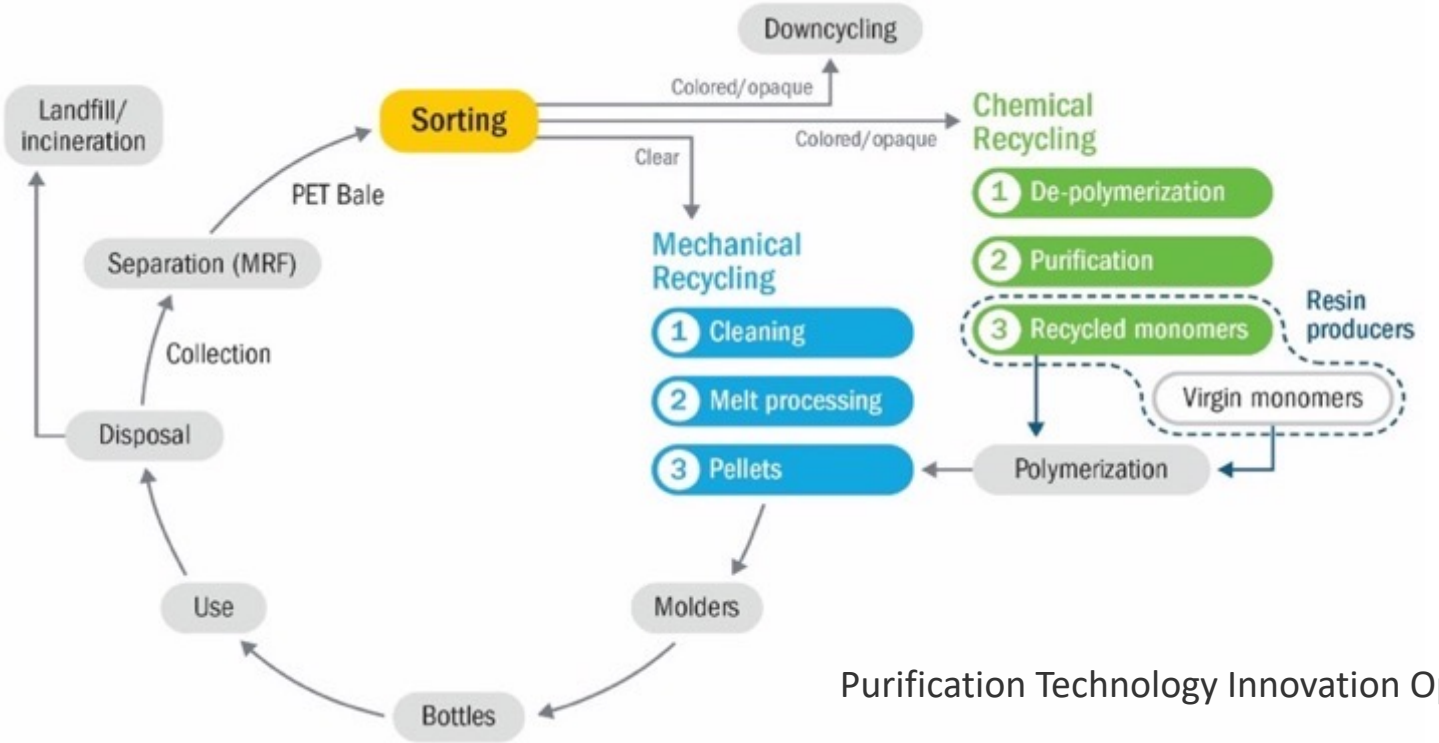


Decarbonization of plastic manufacturing can help us achieve 2030 emissions targets!

Photo: Katmai, Alaska; Max Romney Ocean Plastic Recovery Project

1) Jambeck *et al*. *Science* 2015;
2) Nicholson et al. Joule 2021

PET Recycling in the Future



Purification Technology Innovation Opportunity

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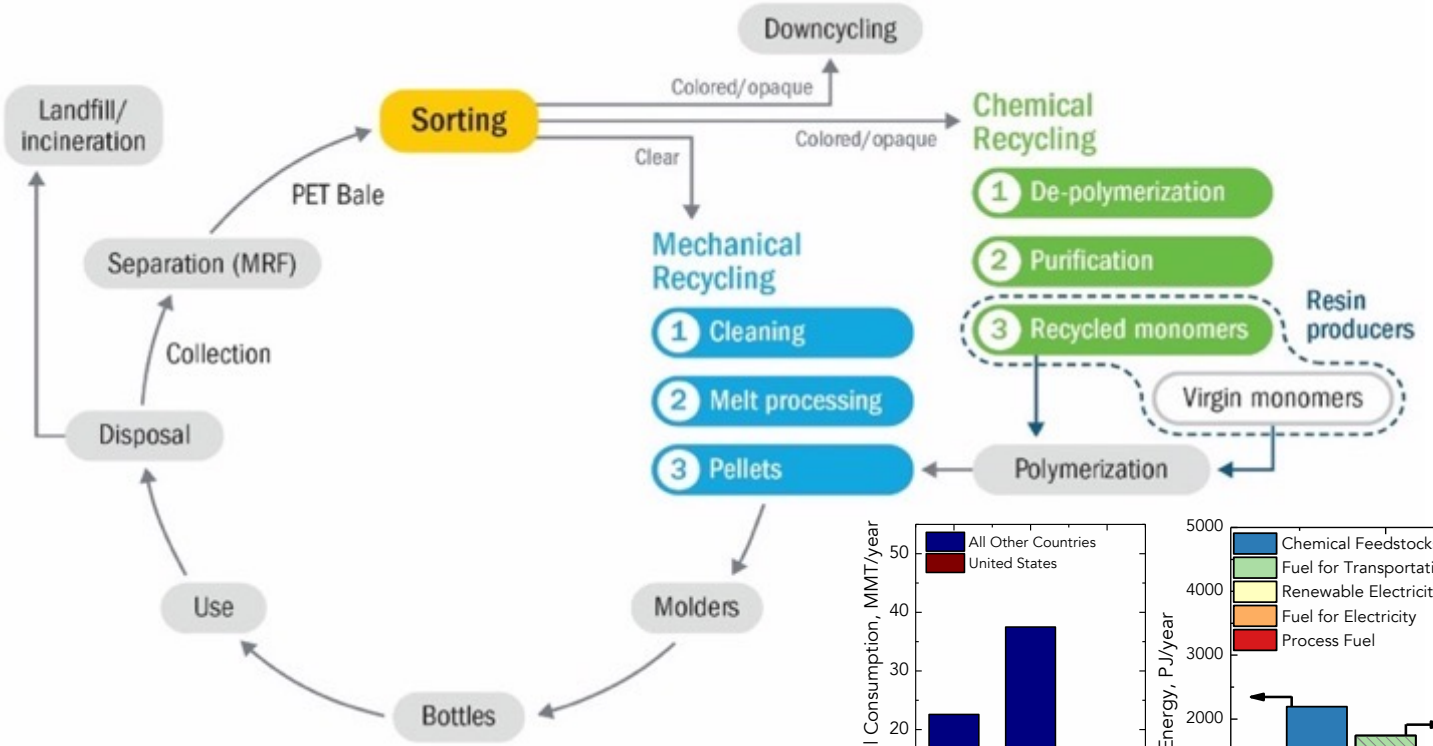
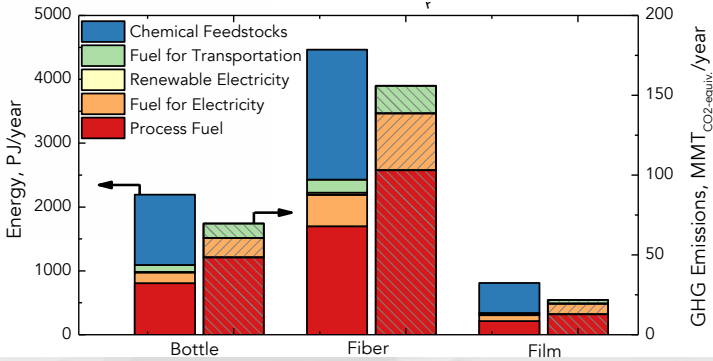
From Martin James and Robert Allen, ACS Symposium Series 'Circular Economy of Polymers' Ed. John Layman (November 2021).

PET Recycling in the Future





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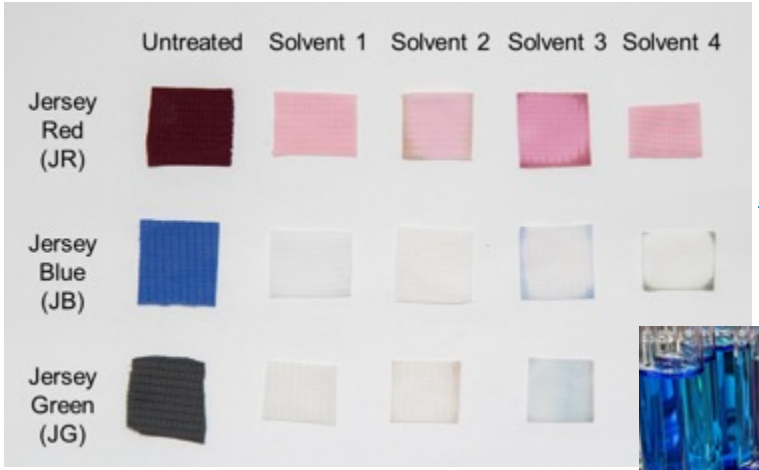
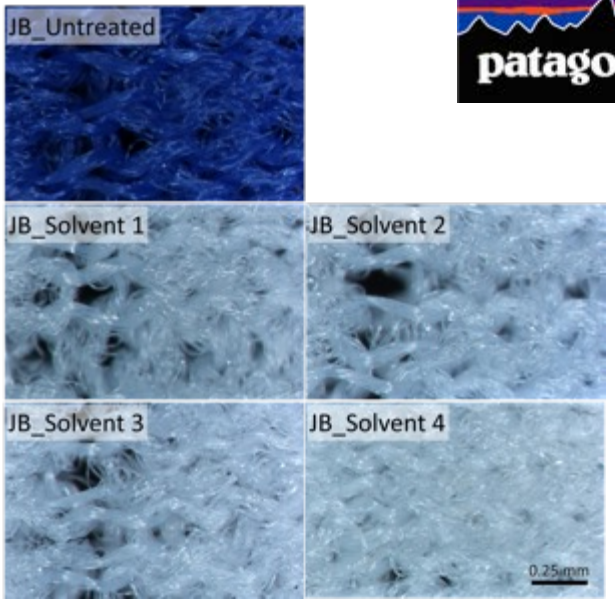
Nicholson, Rorrer, Carpenter and Beckham, "Manufacturing energy and greenhouse gas emissions associated with plastics consumption", Joule, Volume 5, Issue 3, 17 March 2021, Pages 673-686

Dye extraction from PET fabrics in bio-based solvents



Extracted dyes!



For mechanical recycling!

Dr. Minjung Lee

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Rubber has limited end-of-life options and emits GHG

- Despite being the sixth largest produced polymer class, they are the fourth largest contributor to GHG emissions
- Additionally, due to their thermoset nature, they are not recyclable at the end-of-life which results in their disposal or use in downcycled applications and higher environmental leakage potential
- Despite this, tires have a collection infrastructure unlike most commodity materials

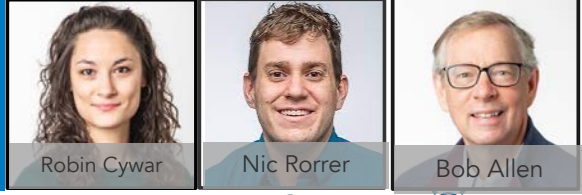
Thus, there is an opportunity and need to Redesign Elastomers for Greater Recyclability

Did You Know?

As much as 28 percent of microplastics in the ocean comes from tires shedding synthetic rubber as they wear down.

https://www.nationalgeographic.com/environment/article/tires-unseen-plastic-polluter

Elastomer Redesign for Degradability



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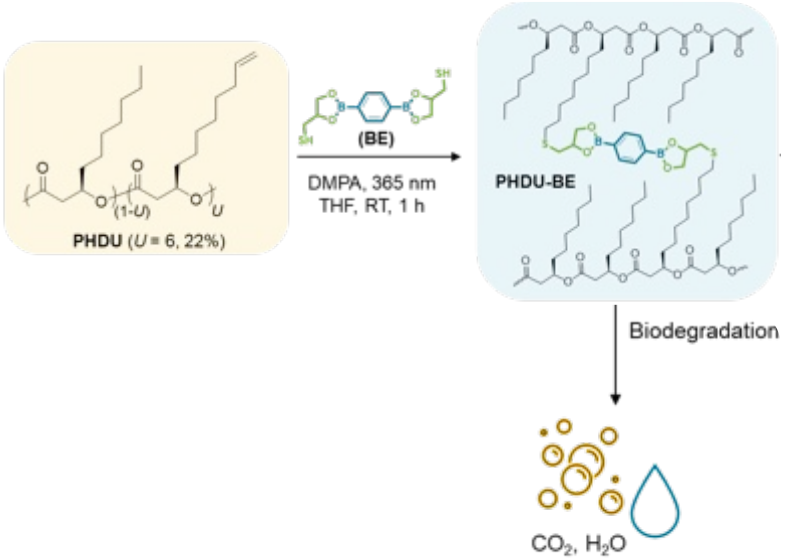
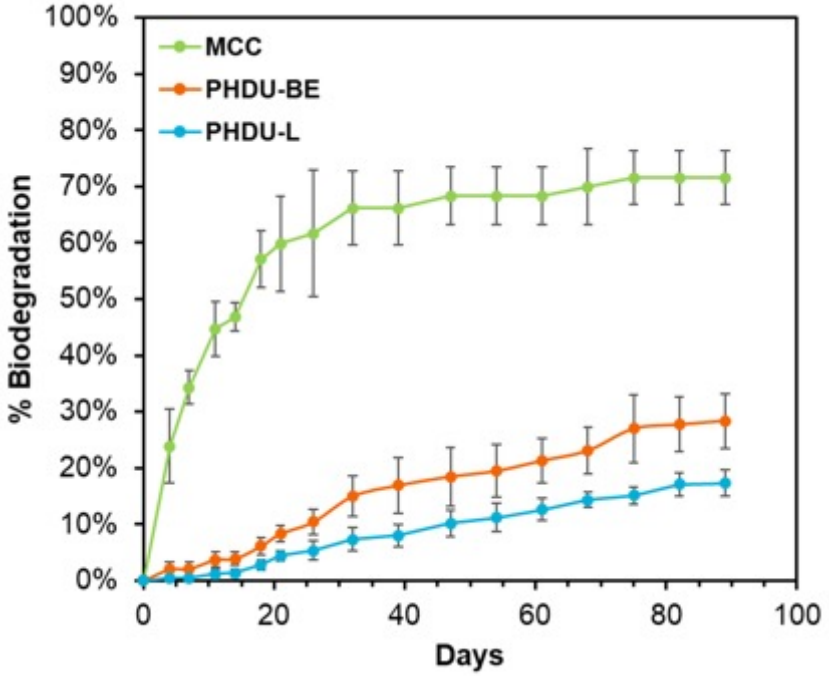


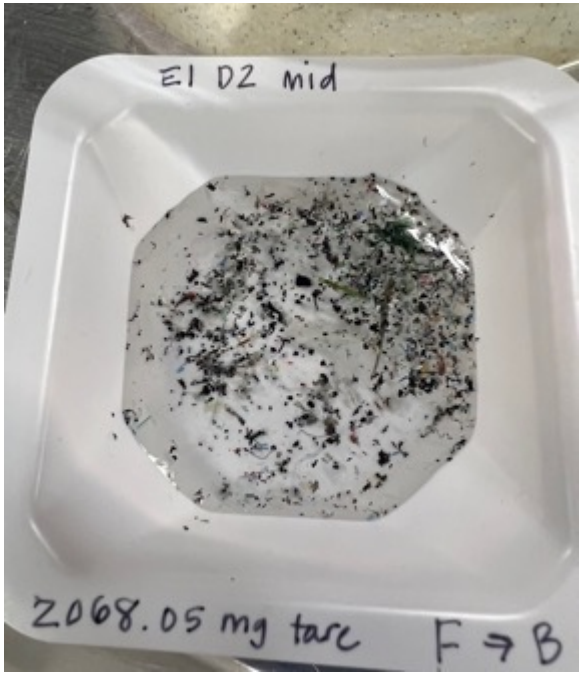


The usPHAs slowly degrade in aquatic conditions and are estimated to degrade in < 2 years

Cywar *et al.* Forthcoming

Tire Dust from the LA River

- NREL/PNNL have a collection and analysis project called WATERPACT.
- Water samples taken from 4 rivers throughout the US, NREL is analyzing plastics content in each.
- Polymer types, additives, degradation products, etc.
- Data to be fed into models.



WaterPact Analysis

Thank You