Special Topic IV: Sustainable Polymers

16:160:509 – Polymer Chemistry

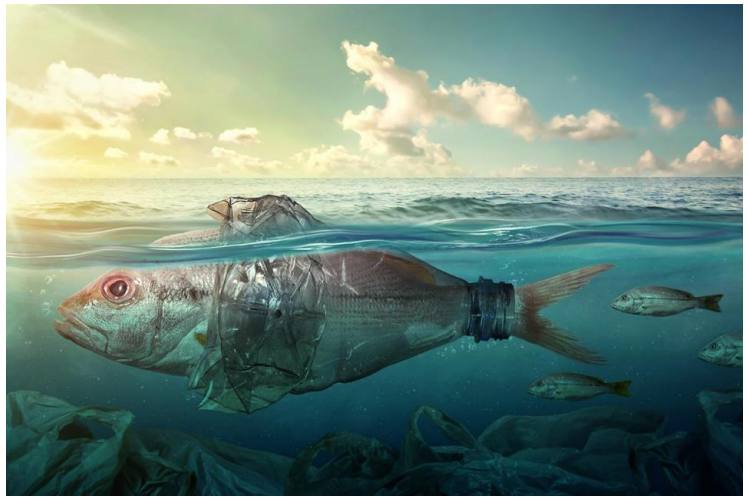
Lecture 23

RUTGERS
School of Arts and Sciences
DEPARTMENT OF CHEMISTRY
AND CHEMICAL BIOLOGY

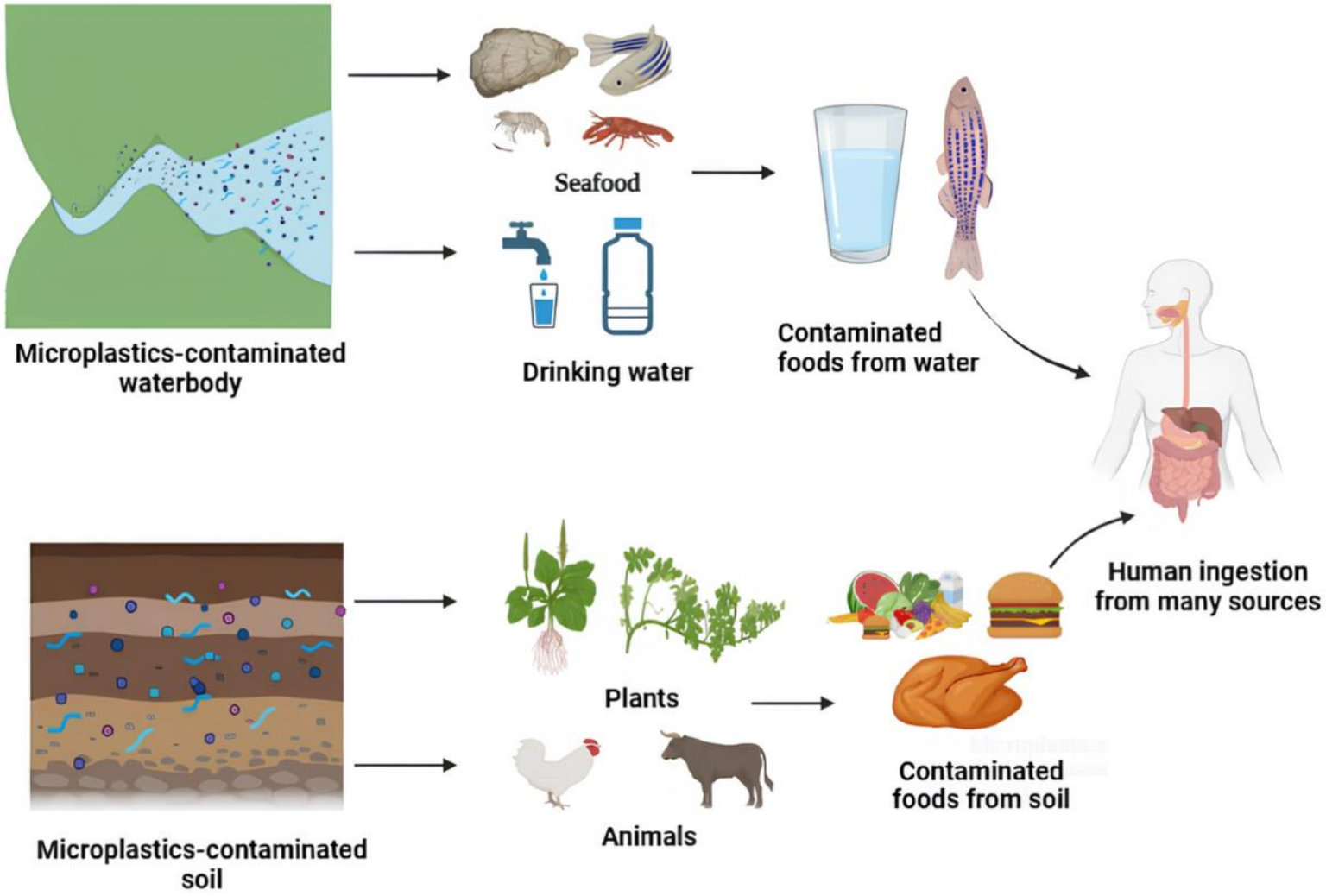
Plastic Packaging

	Original packaging	New packaging	Result
Bananas	Sold loose	Perforated polyethylene bags	Lasted 15 days unpackaged versus 36 days in bags
Beef	Polystyrene foam tray with cling wrap	Vacuum packing in oxygen barrier film	Shelf life extended from four days to up to 30 days
Bell peppers	Sold loose	Modified atmosphere packaging with perforated polypropylene film	Lasted four days sold loose versus 20 days in packaging
Bread	Paper bag	Biaxially oriented polypropylene film	Food waste reduced from 11.0% to 0.8%
Cheese	Sliced at counter and wrapped in paper	Polyester tray with a polyethylene and polyester lid	Food waste reduced from 5.00% to 0.14%
Cucumbers	Sold loose	Polyethylene shrink wrap	Shelf life extended from three days to 14 days
Grapes	Sold loose	Perforated bags	Bagging leads to a 20% reduction in in-store waste

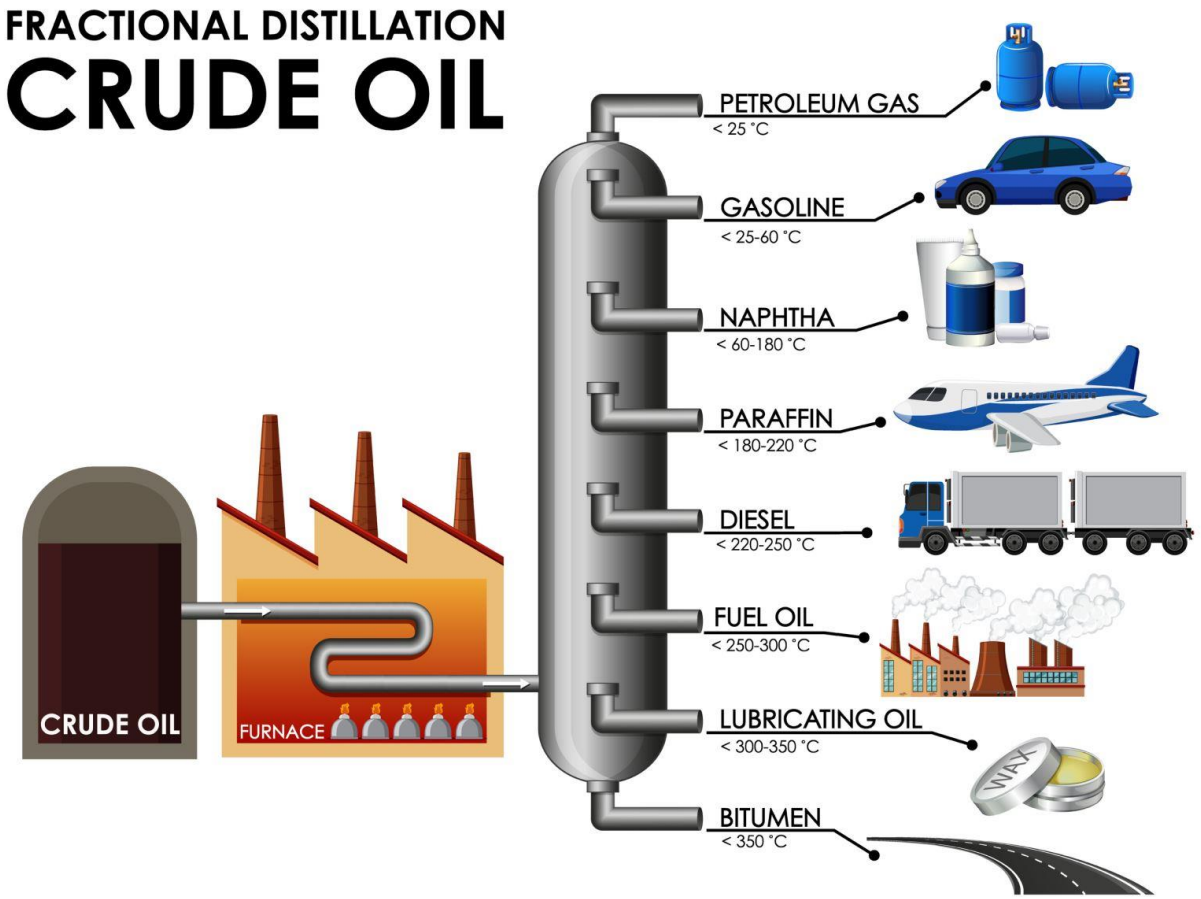
Environmental Problems Associated with Plastics Waste

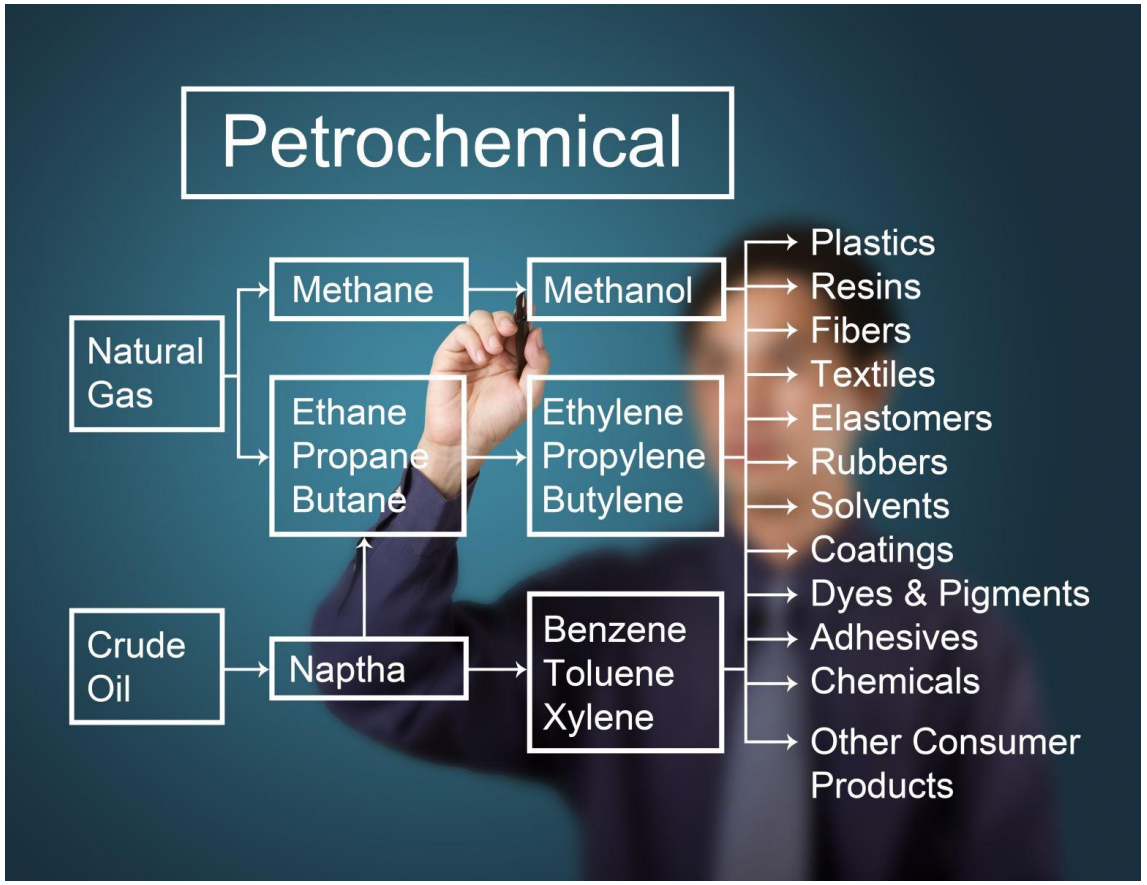


Microplastic Pollution

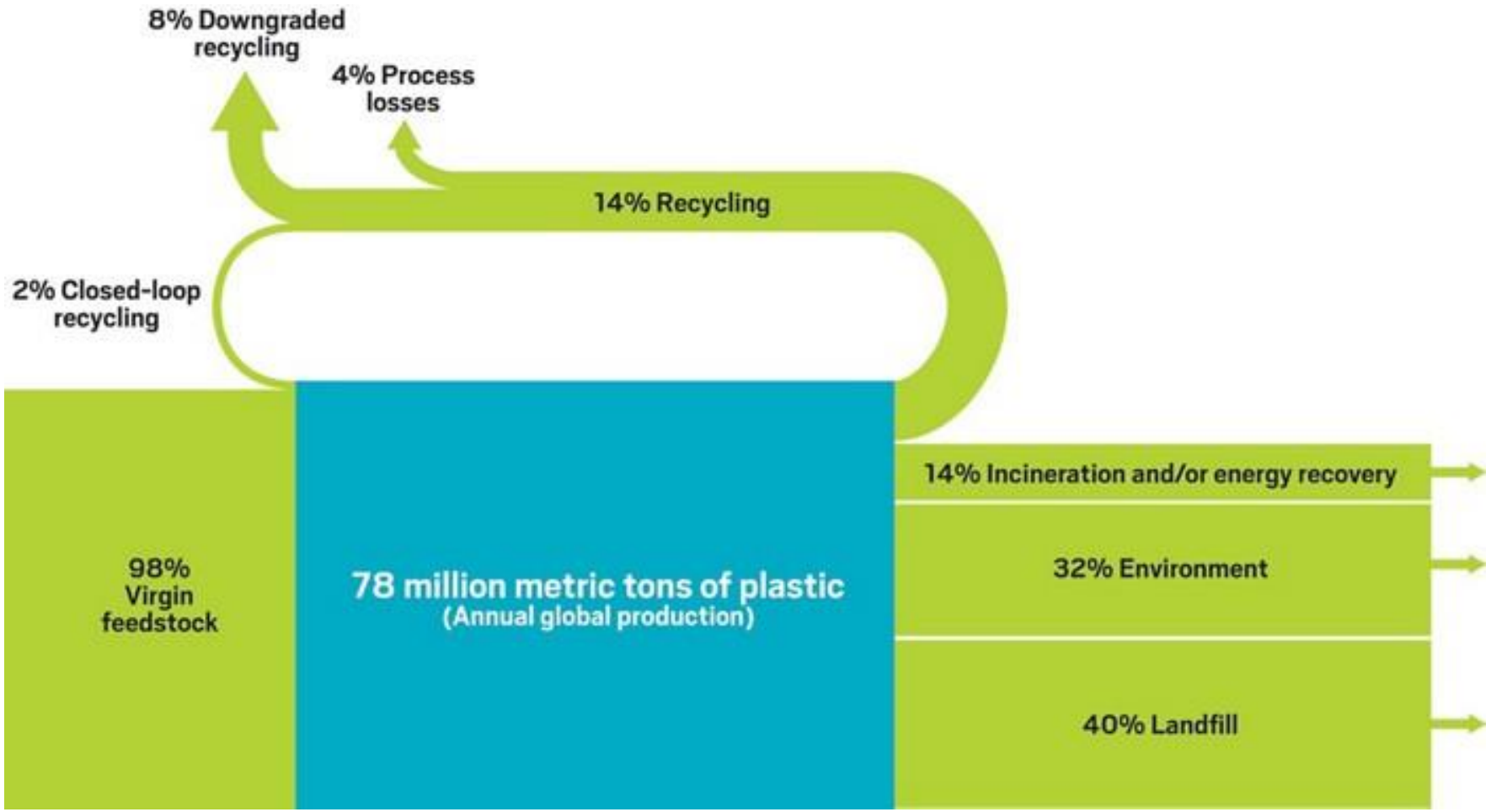


Where Do Polymers Come From?

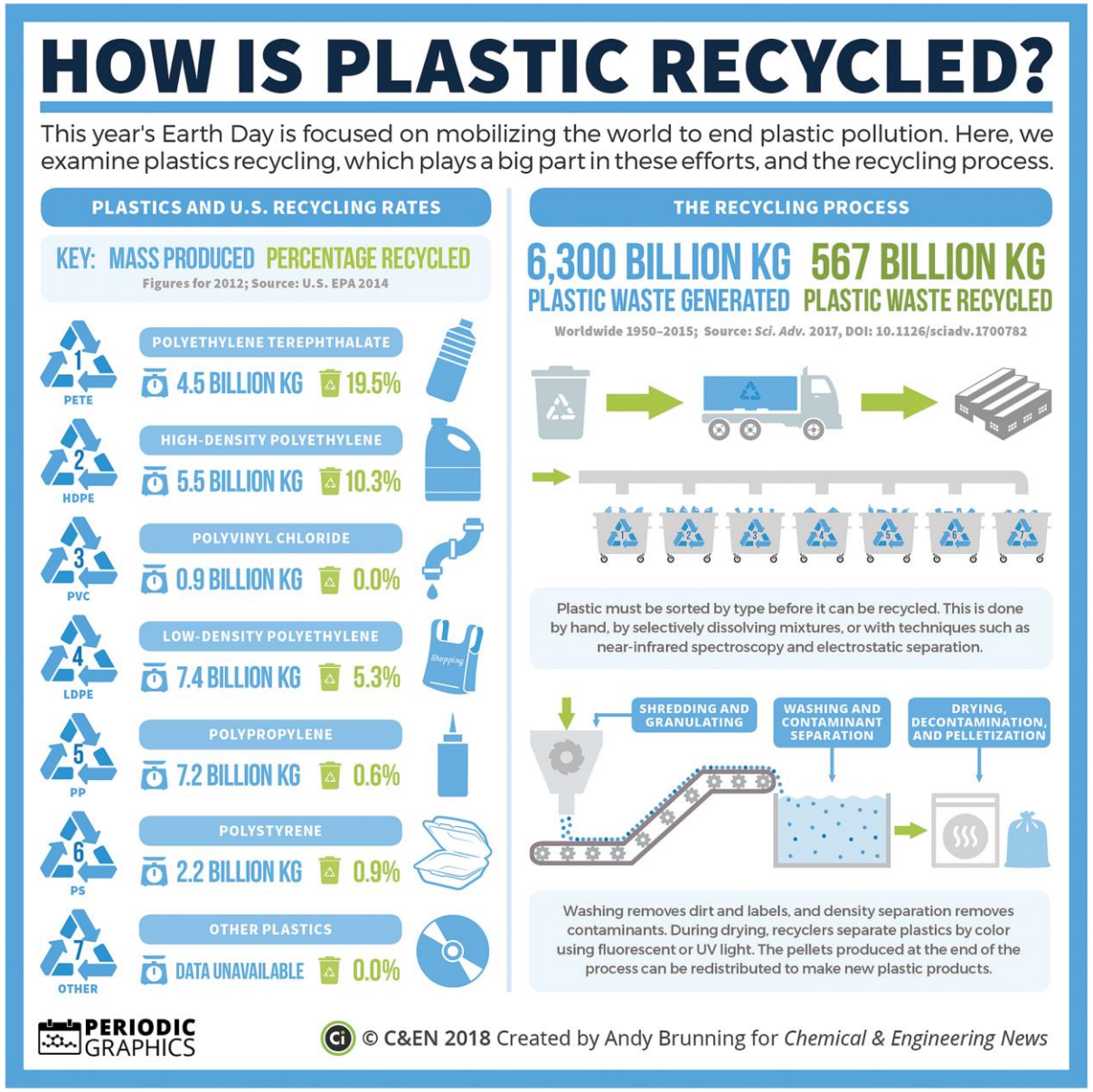




Where Do Polymers Go?



Plastic Recycling

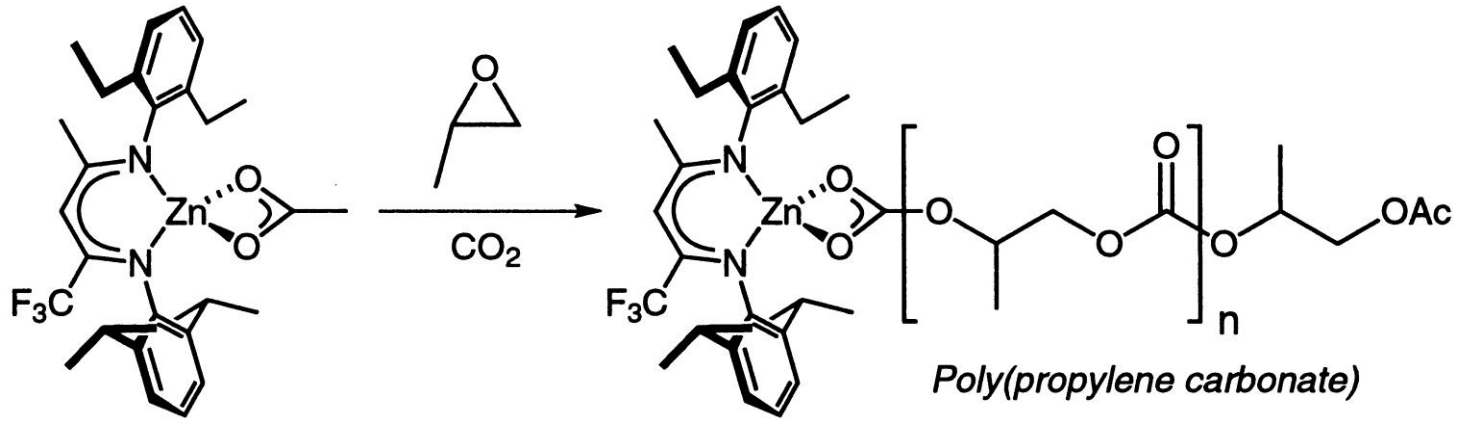


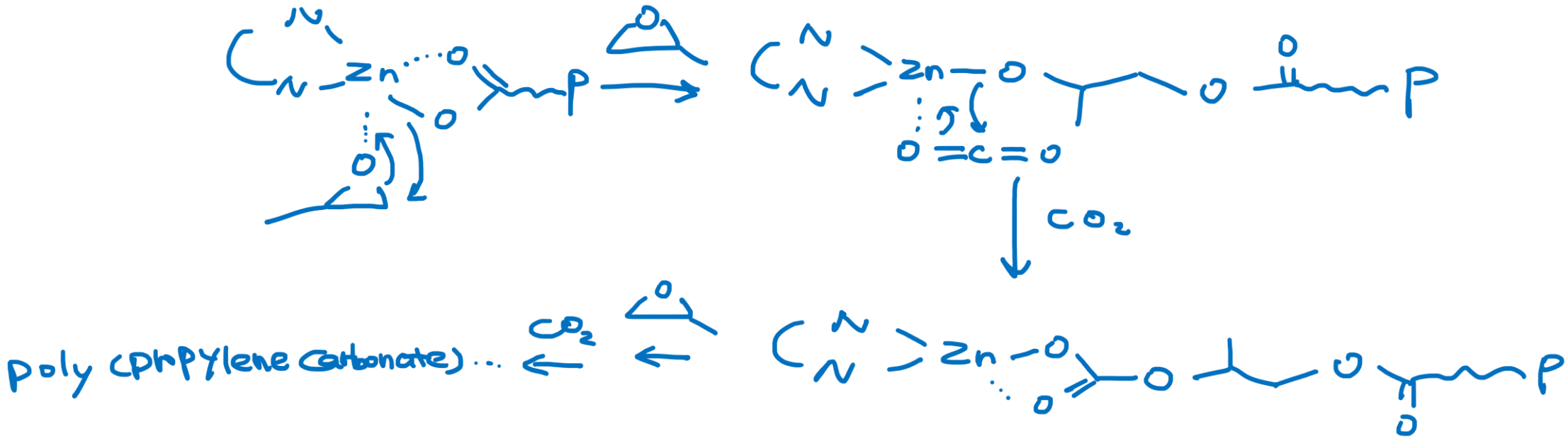
Strategies to Improve the Sustainability of Polymers

- Renewable monomer sources
- New chemical methods for degrading existing polymers
- Developing new degradable polymers
- Closed-loop recycling
- Polymer upcycling
- Reprocessable thermosets

Schneiderman, D. K.; Hillmyer, M. A., *Macromolecules* **2017,** *50*, 3733-3749.

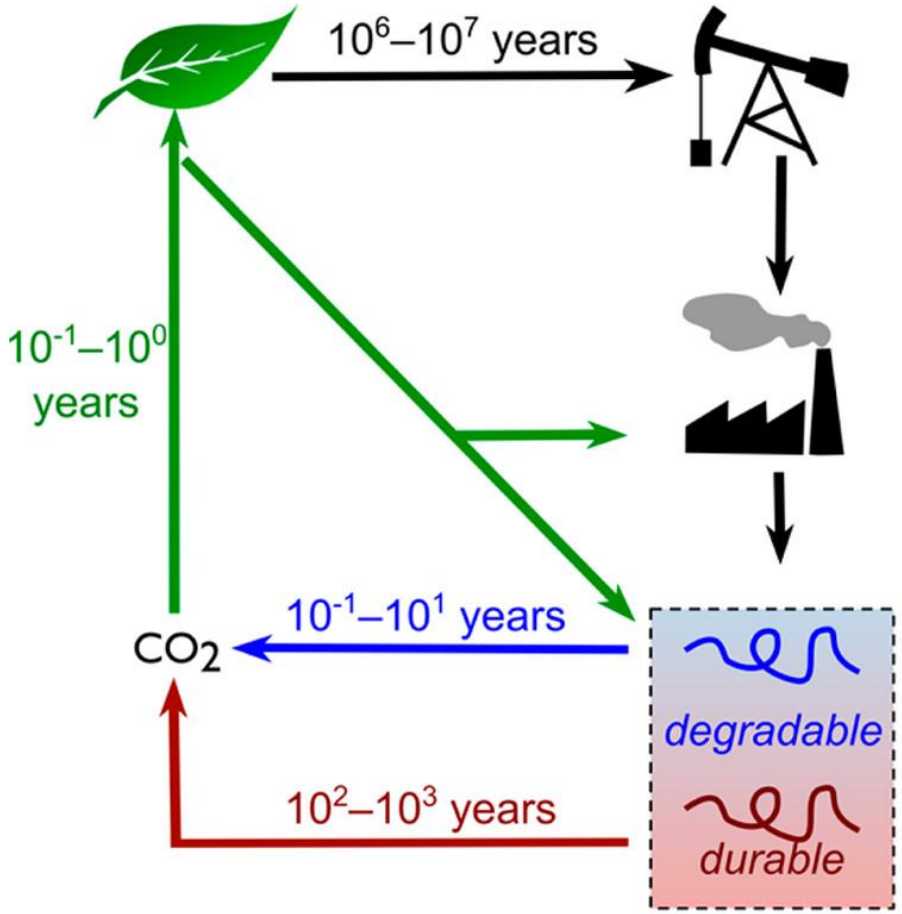
Use CO_2 as a Monomer Stock

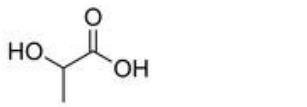




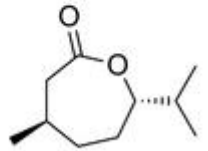
Allen, S. D.; Moore, D. R.; Lobkovsky, E. B.; Coates, G. W., *J. Am. Chem. Soc.* **2002,** *124*, 14284-14285.

Renewable-Resource Thermoplastic Elastomers





lactic acid



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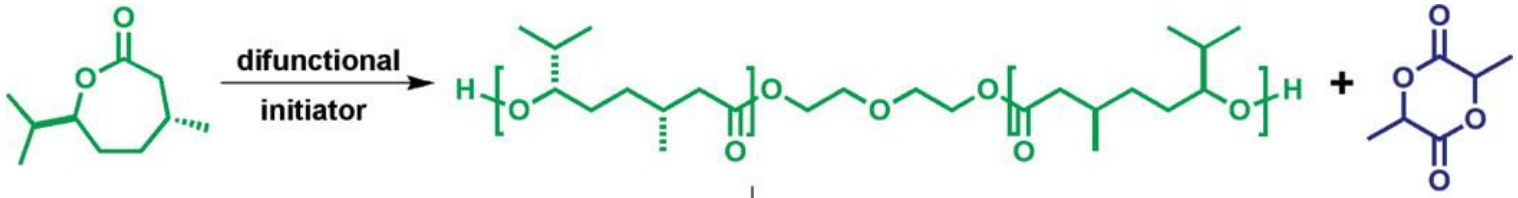
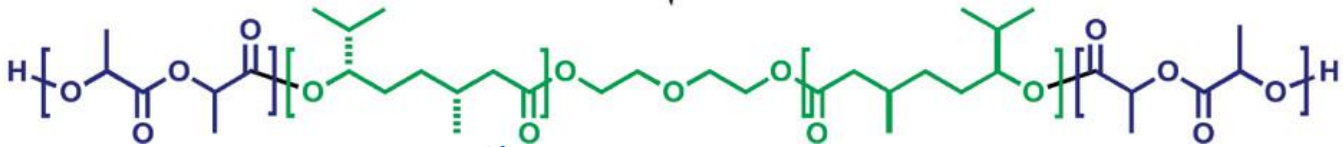
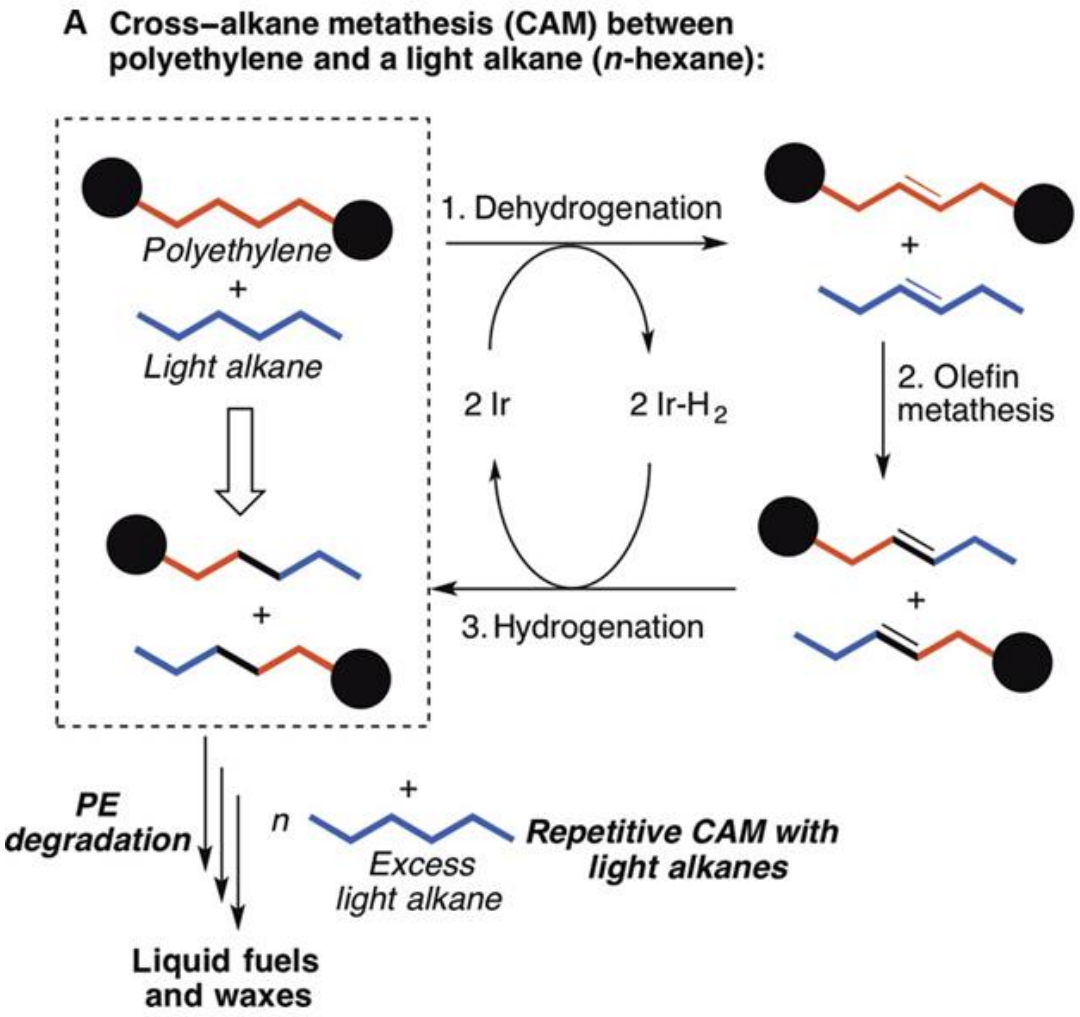


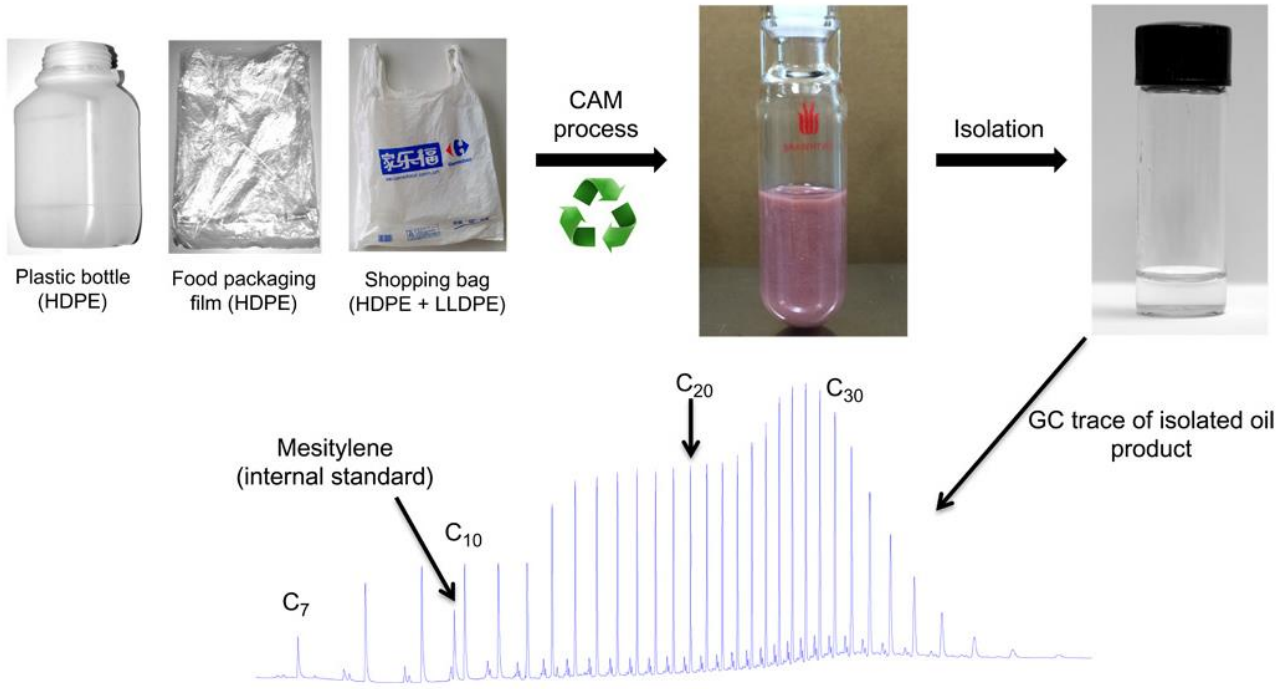


"hard" block "soft" block "hard" block

Wanamaker, C. L.; O'Leary, L. E.; Lynd, N. A.; Hillmyer, M. A.; Tolman, W. B., *Biomacromolecules* **2007,** *8*, 3634-3640.

New Chemistry for Degradation of Polyethylene





Jia, X.; Qin, C.; Friedberger, T.; Guan, Z.; Huang, Z., *Sci. Adv.* **2016,** *2*, e1501591.

Degradable Polymers

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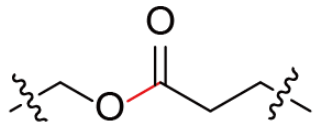
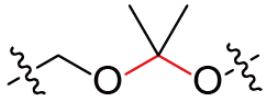
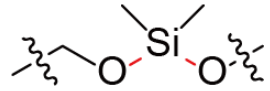
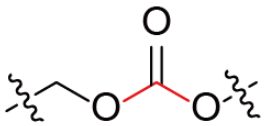
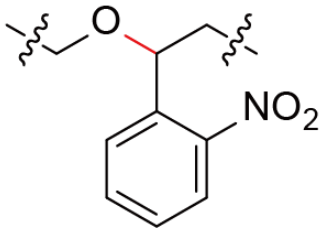
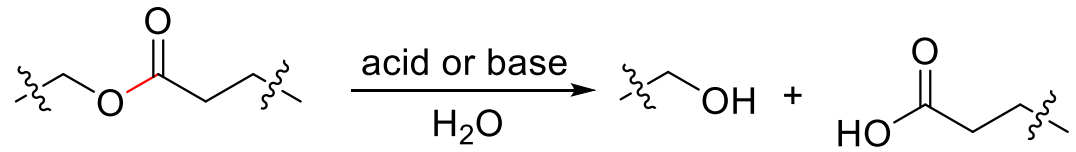


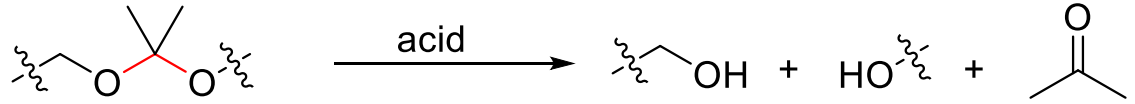


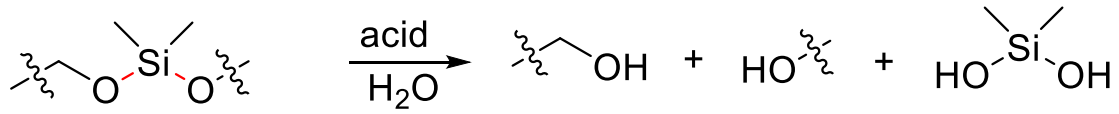


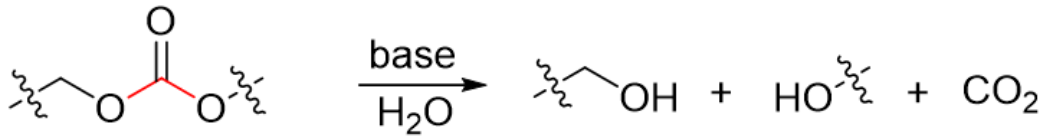


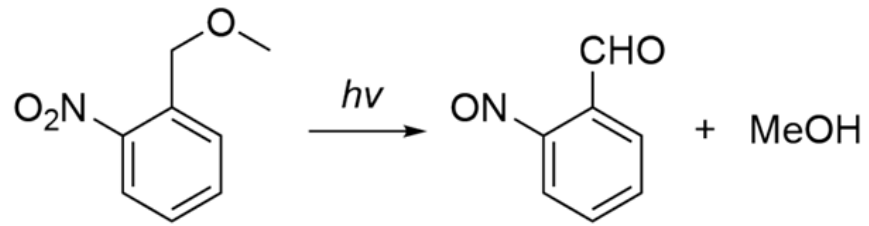




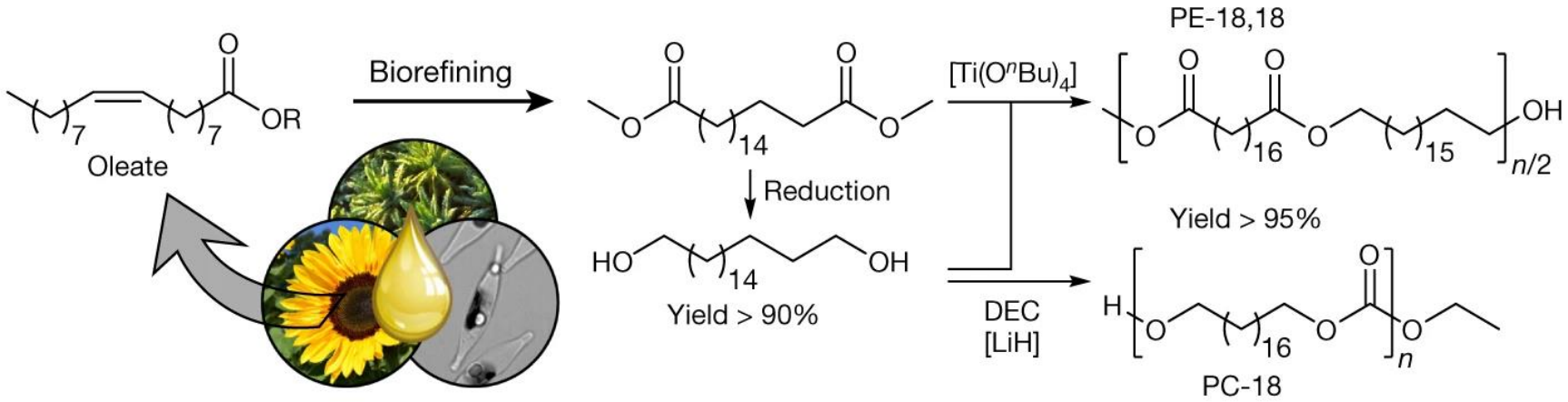




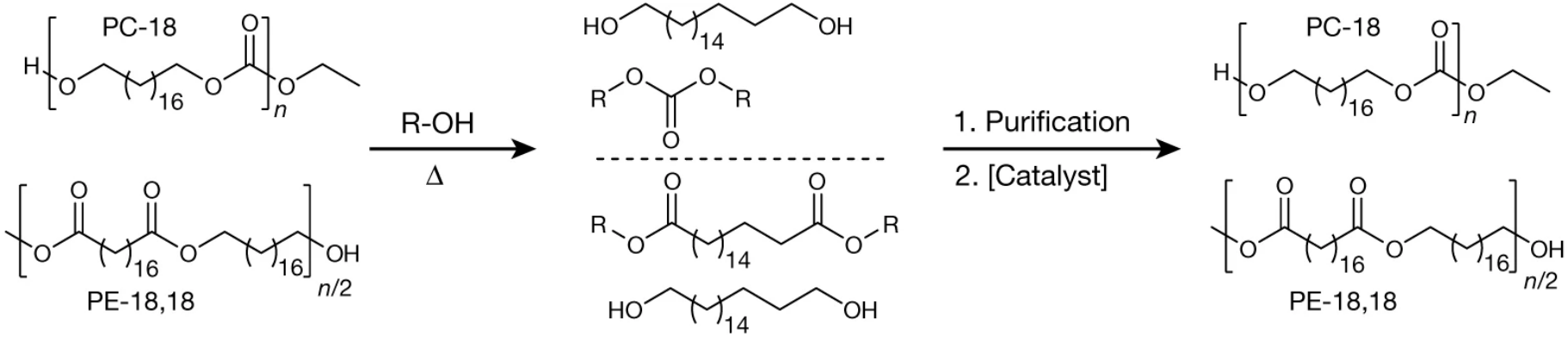


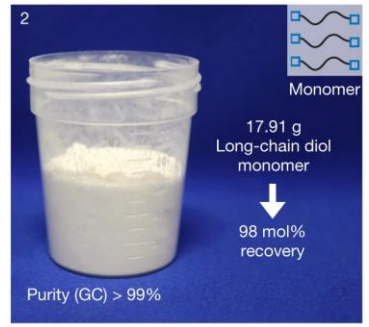


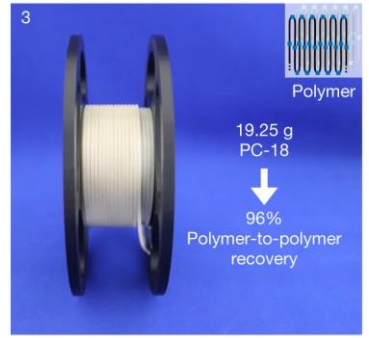
Degradable Polyethylene-Like Materials



The polymers have similar mechanical properties as polyethylene but can be degraded

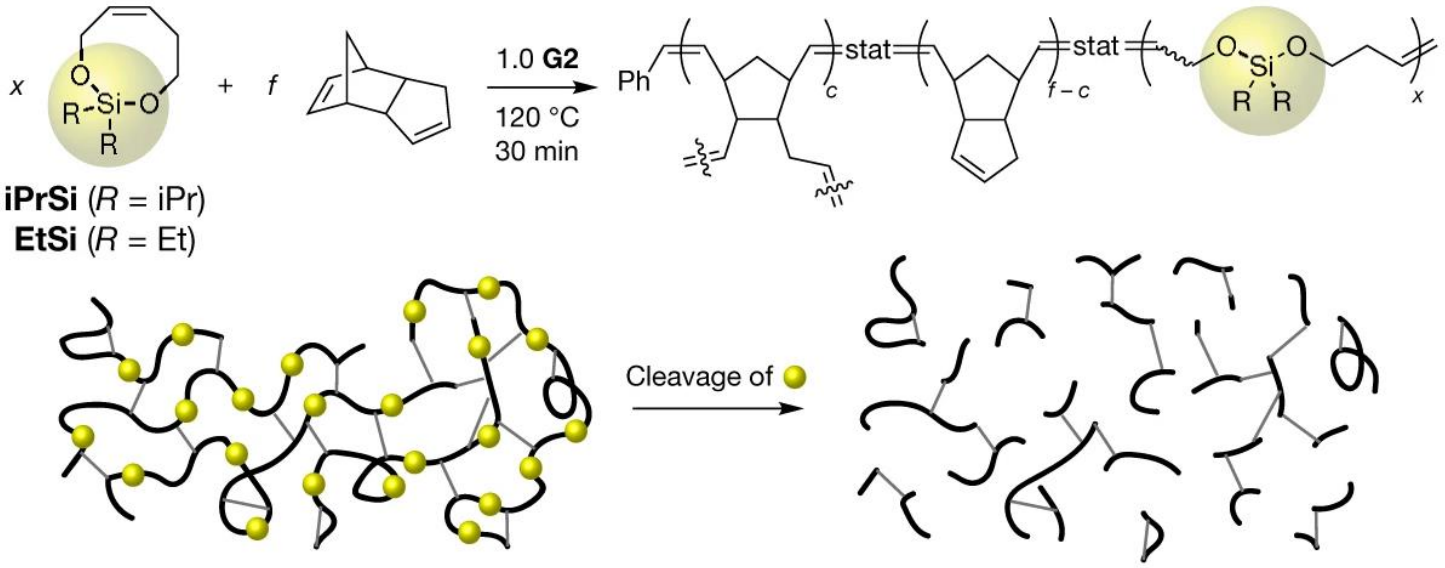


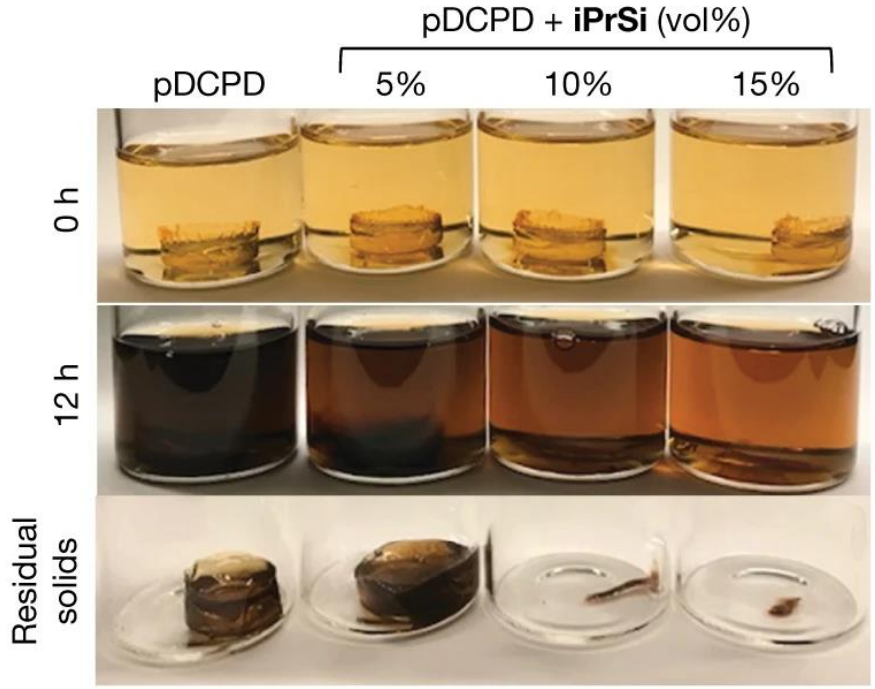




Häußler, M.; Eck, M.; Rothauer, D.; Mecking, S., *Nature* **2021,** *590*, 423-427.

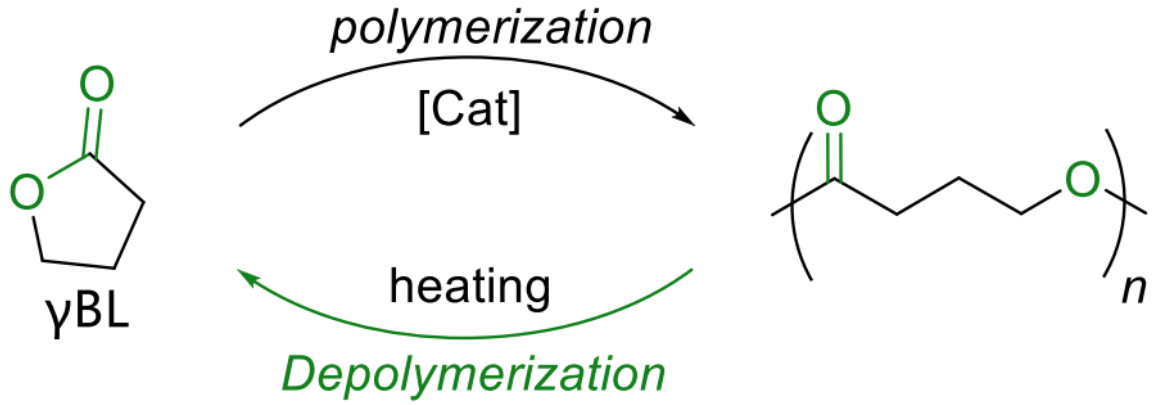
Cleavable Comonomers Enable Degradable Thermoset Plastics

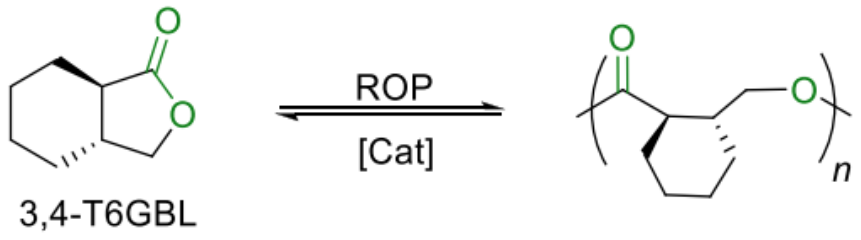


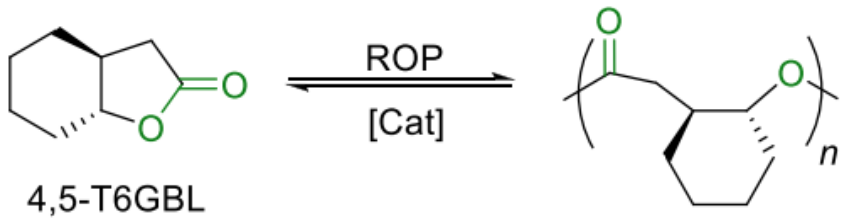


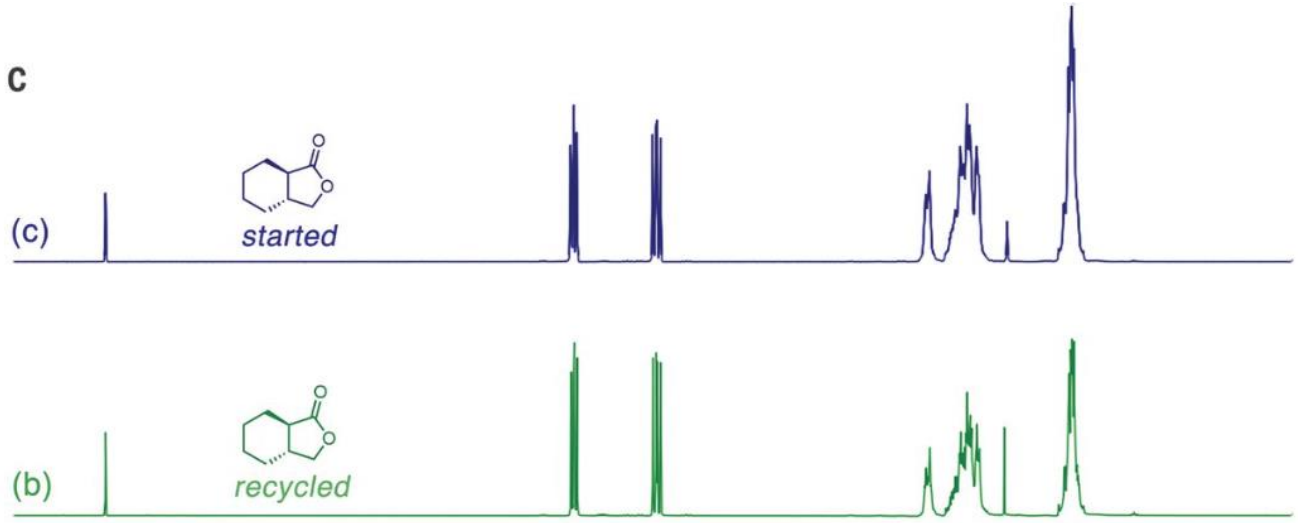
Shieh, P.; Zhang, W.; Husted, K. E. L.; Kristufek, S. L.; Xiong, B.; Lundberg, D. J.; Lem, J.; Veysset, D.; Sun, Y.; Nelson, K. A.; Plata, D. L.; Johnson, J. A., *Nature* **2020,** *583*, 542-547.

Closed-Loop Recycling



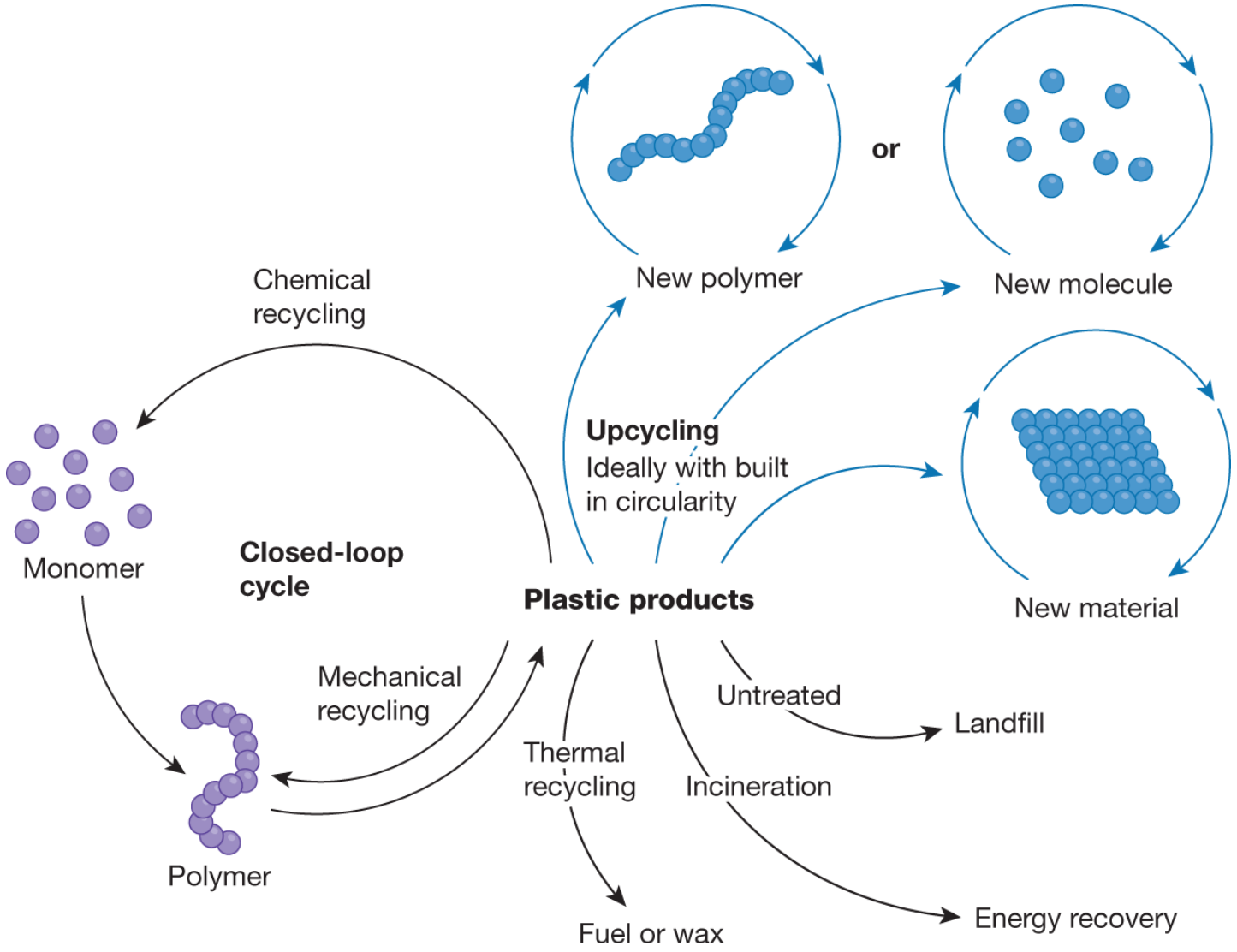




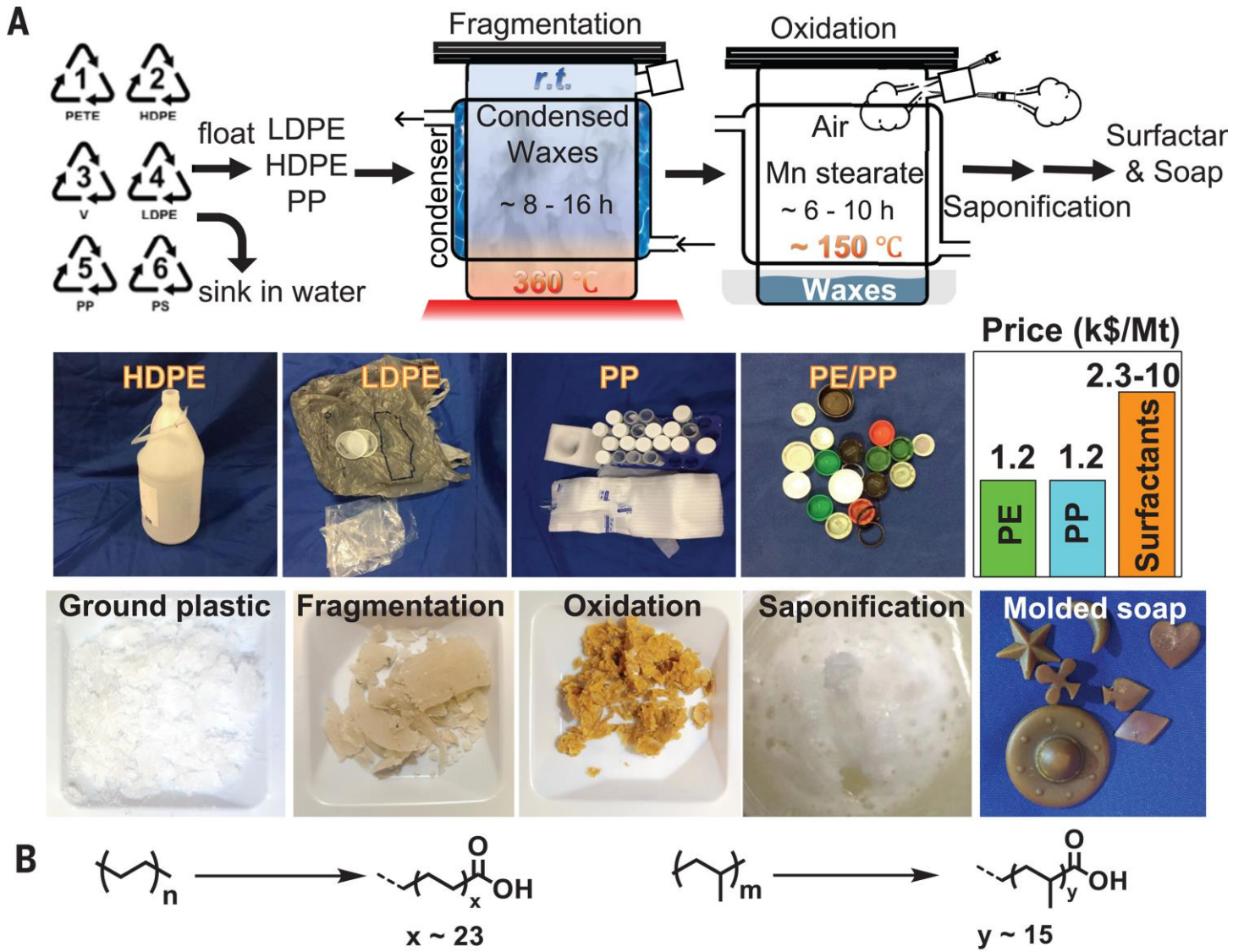


Hong, M.; Chen, E. Y. X., *Nat. Chem.* **2016,** *8*, 42-49.
Zhu, J.-B.; Watson, E. M.; Tang, J.; Chen, E. Y.-X., *Science* **2018,** *360*, 398-403.

Polymer Upcycling

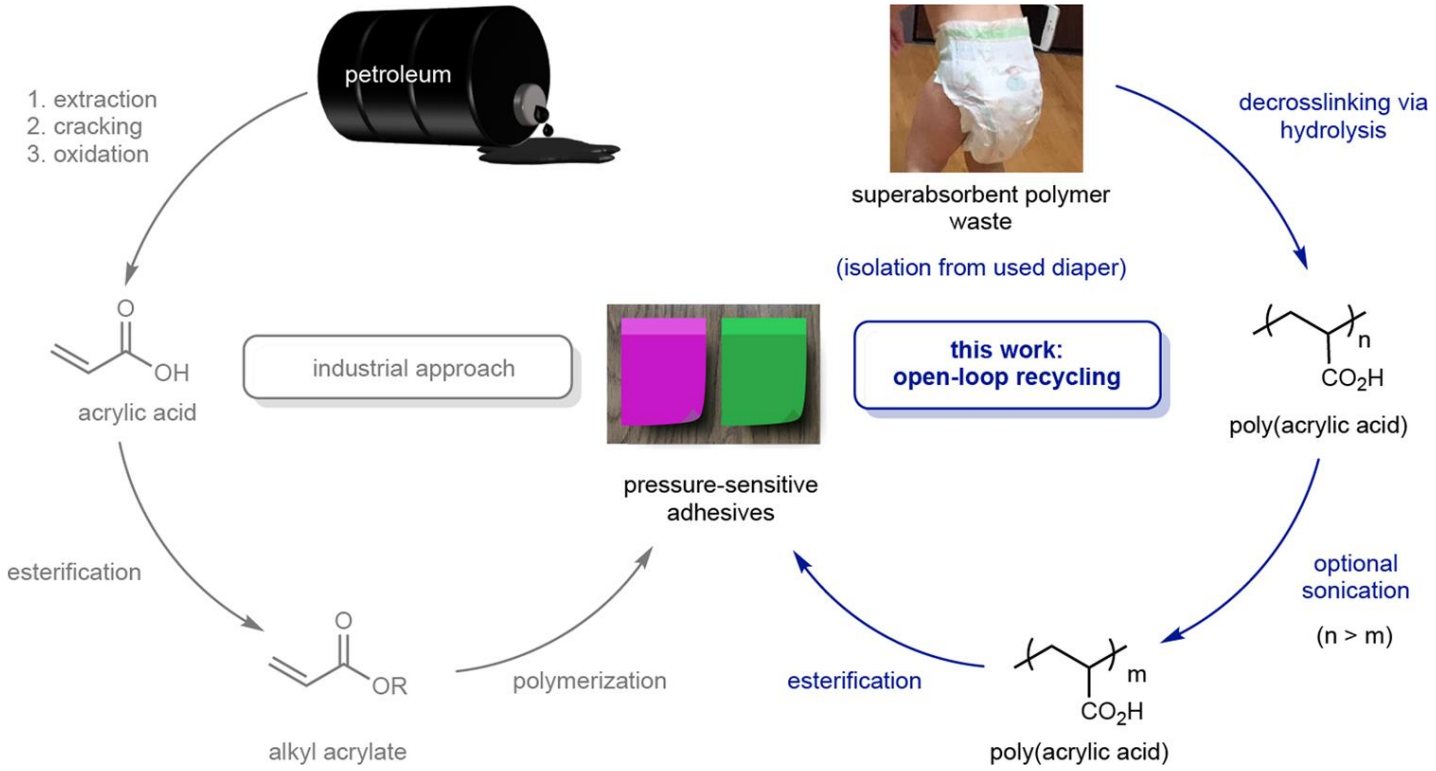


Upcycling of Polymers to High-Value Surfactants



Xu, Z.; Munyaneza, N. E.; Zhang, Q.; Sun, M.; Posada, C.; Venturo, P.; Rorrer, N. A.; Miscall, J.; Sumpter, B. G.; Liu, G., *Science* **2023,** *381*, 666-671.

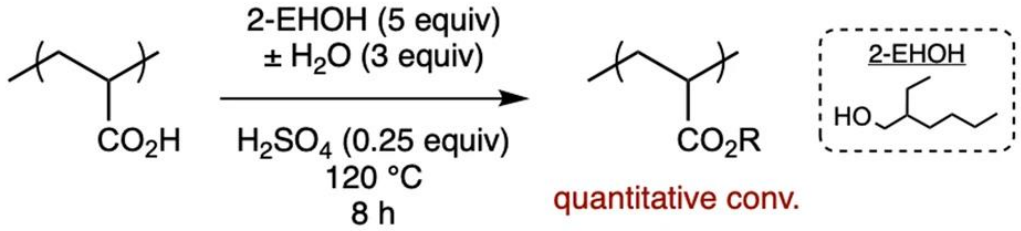
Upcycling of Polymers by Further Functionalization



Giving superabsorbent polymers a second life as pressure-sensitive adhesives

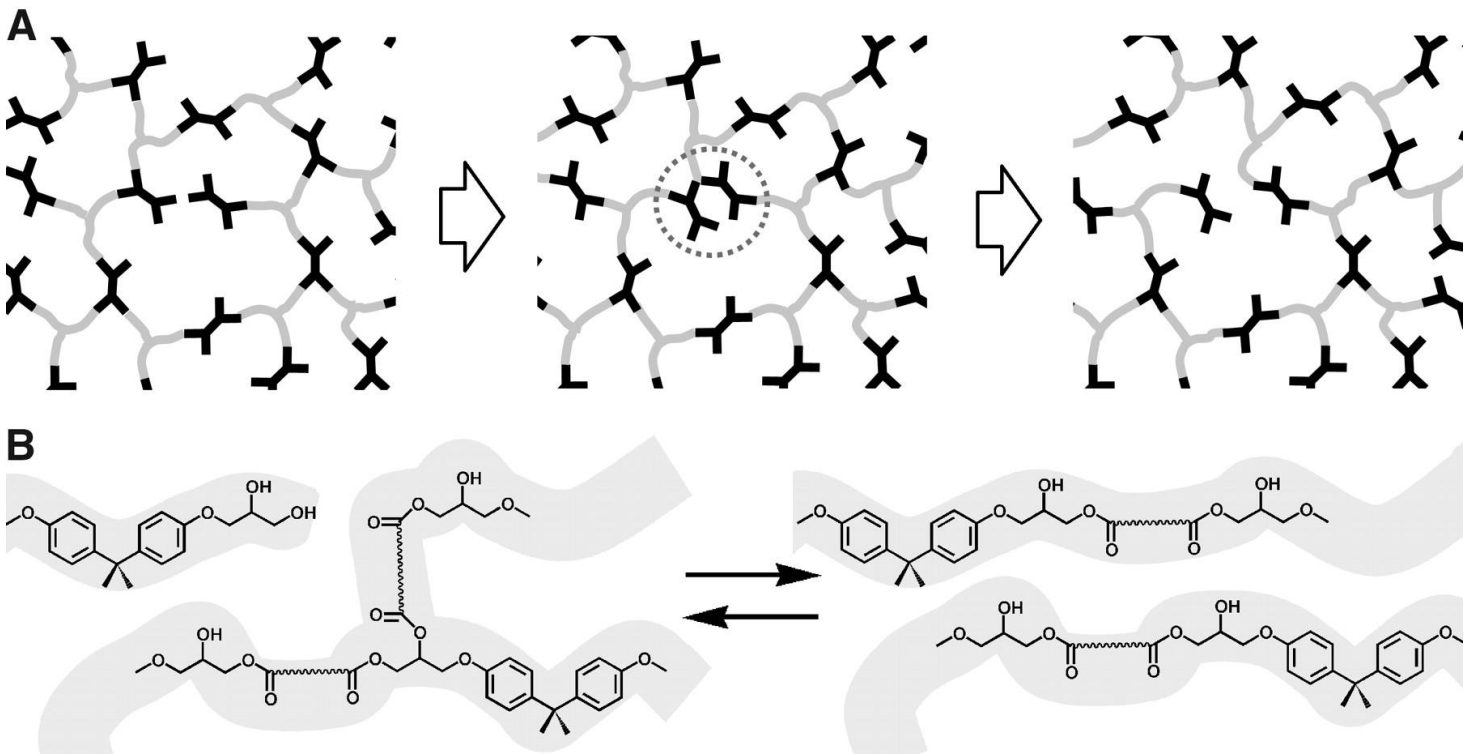
P. Takunda Chazovachii, Madeline J. Somers, Michael T. Robo, Dimitris I. Collias, Martin I. James, E. Neil G. Marsh, Paul M. Zimmerman, Jose F. Alfaro & Anne J. McNeil

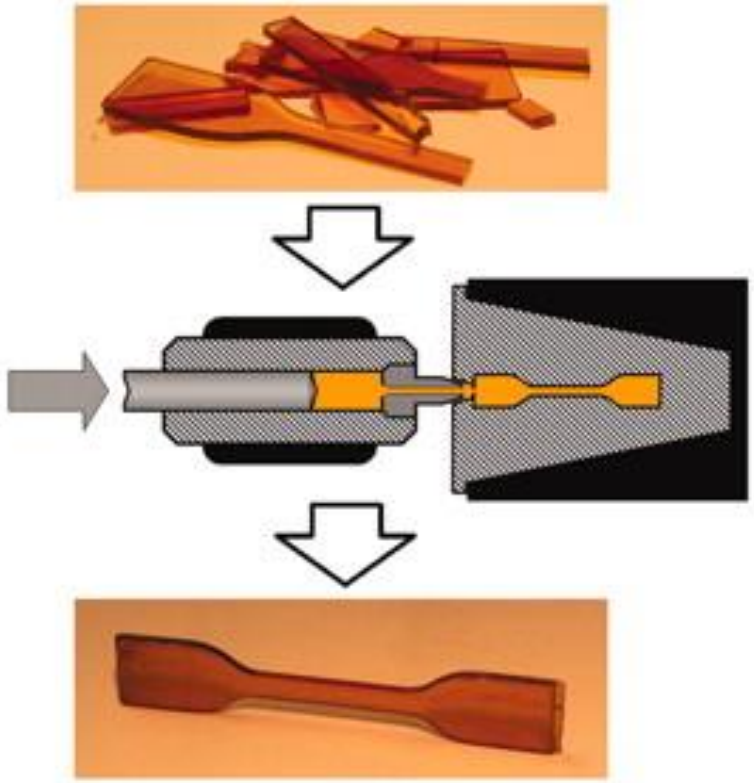
esterification of polymers



Chazovachii, P. T.; Somers, M. J.; Robo, M. T.; Collias, D. I.; James, M. I.; Marsh, E. N. G.; Zimmerman, P. M.; Alfaro, J. F.; McNeil, A. J., *Nat. Commun.* **2021,** *12*, 4524.

Reprocessable Thermosets





Enabling the exchange of covalent bonds within polymer networks leads to remoldable thermosets (“vitrimers”)

Montarnal, D.; Capelot, M.; Tournilhac, F.; Leibler, L., *Science* **2011,** *334*, 965-968.