

# Enzyme-based plastics recycling is more energy efficient, better for environment

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Researchers in the BOTTLE Consortium, including from the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) and the University of Portsmouth, have identified using

enzymes as a more sustainable approach for recycling polyethylene terephthalate (PET), a common plastic in single-use beverage bottles, clothing, and food packaging that are becoming increasingly relevant in addressing the environmental challenge of plastic pollution. An analysis shows enzyme-recycled PET has potential improvement over conventional, fossil-based methods of PET production across a broad spectrum of energy, carbon, and socioeconomic impacts.

The concept, if further developed and implemented at scale, could lead to new opportunities for PET [recycling](#) and create a mechanism for recycling textiles and other materials also made from PET that are traditionally not recycled today. PET ranks among the most abundantly produced synthetic polymers in the world, with 82 million metric tons produced annually; roughly 54% of PET is used in the manufacture of textiles for clothing and fibers for carpet.

"From all the plastics that were produced since the 1950s, less than 10% of it has ever been recycled," said Avantika Singh, a [chemical engineer](#) at NREL and first author of a new paper outlining the path toward enzyme-based recycling. "Most waste plastics end up in landfills."

The paper, "Techno-economic, life-cycle, and socioeconomic impact analysis of enzymatic recycling of poly(ethylene terephthalate)," appears in the journal *Joule*. Her coauthors are Nicholas Rorrer, Scott Nicholson, Erika Erickson, Jason DesVeaux, Andre Avelino, Patrick Lamers, Arpit Bhatt, Yi Min Zhang, Greg Avery, Ling Tao, Alberta Carpenter, and Gregg Beckham, all from NREL; and John McGeehan and Andrew Pickford of the University of Portsmouth's Centre for Enzyme Innovation in the United Kingdom, who are also members of BOTTLE.



An NREL researcher observes visible changes in bioreactors used to test enzymatic degradation of PET plastic. In reactors loaded with less enzyme, the liquid appears unclouded and the plastic remains transparent. In reactors loaded with more enzyme, the liquid is cloudy and the plastic becomes opaque, as shown here. Credit: Dennis Schroeder, NREL

BOTTLE is striving to address the problem of [plastic](#) pollution with two innovative approaches, namely to: (1) develop energy-efficient, cost-effective, and scalable recycling and upcycling technologies and (2) design modern plastics to be recyclable by design.

The new research paper addresses the challenge of plastic recyclability. While images of discarded bottles floating in oceans and other waterways provide a visual reminder of the problems posed by plastic

waste, the lesser-seen issue remains of what to do with the PET used to manufacture textiles for clothing and fibers for carpet.

The researchers modeled a conceptual recycling facility that would take in a fraction of the 3 million metric tons of PET consumed annually in the United States. The enzymatic recycling process breaks down PET into its two building blocks, terephthalic acid (TPA) and ethylene glycol. Compared to conventional fossil-based production routes, the research team determined the enzymatic recycling process can reduce total supply-chain energy use by 69%-83% and greenhouse gas emissions by 17%-43% per kilogram of TPA. Additionally, an economy-wide comparison of virgin TPA and recycled TPA in the United States shows that the environmental and socioeconomic effects of the two processes are not distributed equally across their supply chain. The proposed recycling process can reduce environmental impacts by up to 95%, while generating up to 45% more socioeconomic benefits, including local jobs at the material recovery facilities.

The study also predicts that enzymatic PET recycling can achieve cost parity with the production of virgin PET, thus highlighting the potential for this enzyme technology to decarbonize PET manufacturing, in addition to enabling the recycling of waste PET-rich feedstocks, such as clothing and carpets.

"That's one of the biggest opportunities," Singh said. "If we can capture that space—textiles, carpet fibers, and other PET waste plastics that are not currently recycled—that could be a true game-changer."

**More information:** Avantika Singh et al, Techno-economic, life-cycle, and socioeconomic impact analysis of enzymatic recycling of poly(ethylene terephthalate) *Joule* (2021). [DOI: 10.1016/j.joule.2021.06.015](https://doi.org/10.1016/j.joule.2021.06.015)

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