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A Plastics Recycling Breakthrough

Scientists from the [University of Illinois Urbana-Champaign](#), [UC Santa Barbara](#) and [Dow](#) have developed a breakthrough process to transform the most widely produced plastic — polyethylene (PE) — into the second-most widely produced plastic, polypropylene (PP), which could reduce greenhouse gas emissions (GHG).

“The world needs more and better options for extracting the energy and molecular value from its waste plastics,” said co-lead author [Susannah Scott](#), Distinguished Professor and Mellichamp Chair of Sustainable Catalytic Processing at UC Santa Barbara. Conventional plastic recycling methods result in low-value plastic molecules and thus offer little incentive to recycle the mountains of plastic waste that have accumulated over the past several decades. But, Scott added, “turning polyethylene into propylene, which can then be used to make a new polymer, is how we start to build a circular economy for plastics.”

“We started by conceptualizing this approach and demonstrated its promise first through theoretical modeling — now we have proved that it can be done experimentally in a way that is scalable and potentially applicable to current industry demands,” said co-lead author [Damien Guironnet](#), a professor of [chemical and biomolecular engineering](#) at Illinois, who published the [first study](#) outlining the necessary catalytic reactions in 2020.

The [new study](#), published in the Journal of the American Chemical Society, announces a series of coupled catalytic reactions that transform PE, which is #2 and #4 plastic that make up 29% of the world’s plastic consumption, into the building

block propylene that is the key ingredient to produce PP, also known as #5 plastic that accounts for close to 25% of the world's plastic consumption.

This study establishes a proof-of-concept for upcycling PE plastic with more than 95% selectivity into propylene. The researchers have built a reactor that creates a continuous flow of propylene that can be converted into PP easily using current technology — making this discovery scalable and rapidly implementable.

“Our preliminary analysis suggests that if just 20% of the world's PE could be recovered and converted via this route, it could represent a potential savings of GHG emissions comparable to taking 3 million cars off the road,” said Garrett Strong, a graduate student associated with the project.

The goal is to cut each very long PE molecule many times to obtain many small pieces, which are the propylene molecules. First, a catalyst removes hydrogen from the PE, creating a reactive location on the chain. Next, the chain is split in two at this location using a second catalyst, which caps the ends using ethylene. Finally, a third catalyst moves the reactive site along the PE chain so the process can be repeated. Eventually, all that is left are a large number of propylene molecules.

“Think of cutting a baguette in half, and then cutting precisely-sized pieces off the end of each half — where the speed at which you cut controls the size of each slice,” Guironnet said.

“Now that we have established the proof of concept, we can start to improve the efficiency of the process by designing catalysts that are faster and more productive, making it possible to scale up,” Scott said. “Since our end-product is already compatible with current industry separation processes, better catalysts will make it possible to implement this breakthrough rapidly.”

The work presented in this publication is highly complementary to a [paper](#) published in Science. Both groups used virgin plastics and similar chemistries. However, the Science team used a different process in an enclosed batch reactor, requiring much higher pressure — which is energy intensive — and the need to recycle more ethylene.

“If we are to upcycle a significant fraction of the over 100 million tons of plastic waste we generate each year, we need solutions that are highly scalable,” Guironnet said. “Our team demonstrated the chemistry in a flow reactor we developed to

produce propylene highly selectively and *continuously*. This is a key advance to address the immense volume of the problem that we are facing.”

Dow researchers were also involved in this work. “Dow is taking a leading role in driving a more circular economy by designing for circularity, building new business models for circular materials and partnering to end plastic waste,” said Dow senior scientist and co-author Ivan Konstantinov. “As a funder of this project, we are committed to finding new ways to eliminate plastic waste and are encouraged by this approach.”

About UC Santa Barbara

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.