U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Three states of plastic degradation using plastic-eating enzymes. The Strategy for Plastics Innovation outlines key research areas and innovations for fostering an energy-efficient plastics future for a circular carbon economy. *Photo courtesy of Dennis Schroeder, National Renewable Energy Laboratory 64234.*

Deconstruct, Upcycle, Redesign: The U.S. Department of Energy Strategy for Plastics Innovation

Plastics are versatile, durable, lightweight, and cost-effective compared to other materials. Although in many applications they provide greenhouse gas (GHG) reduction benefits across the supply chain,[1] they also represent a substantial roadblock to a green and decarbonized circular economy.

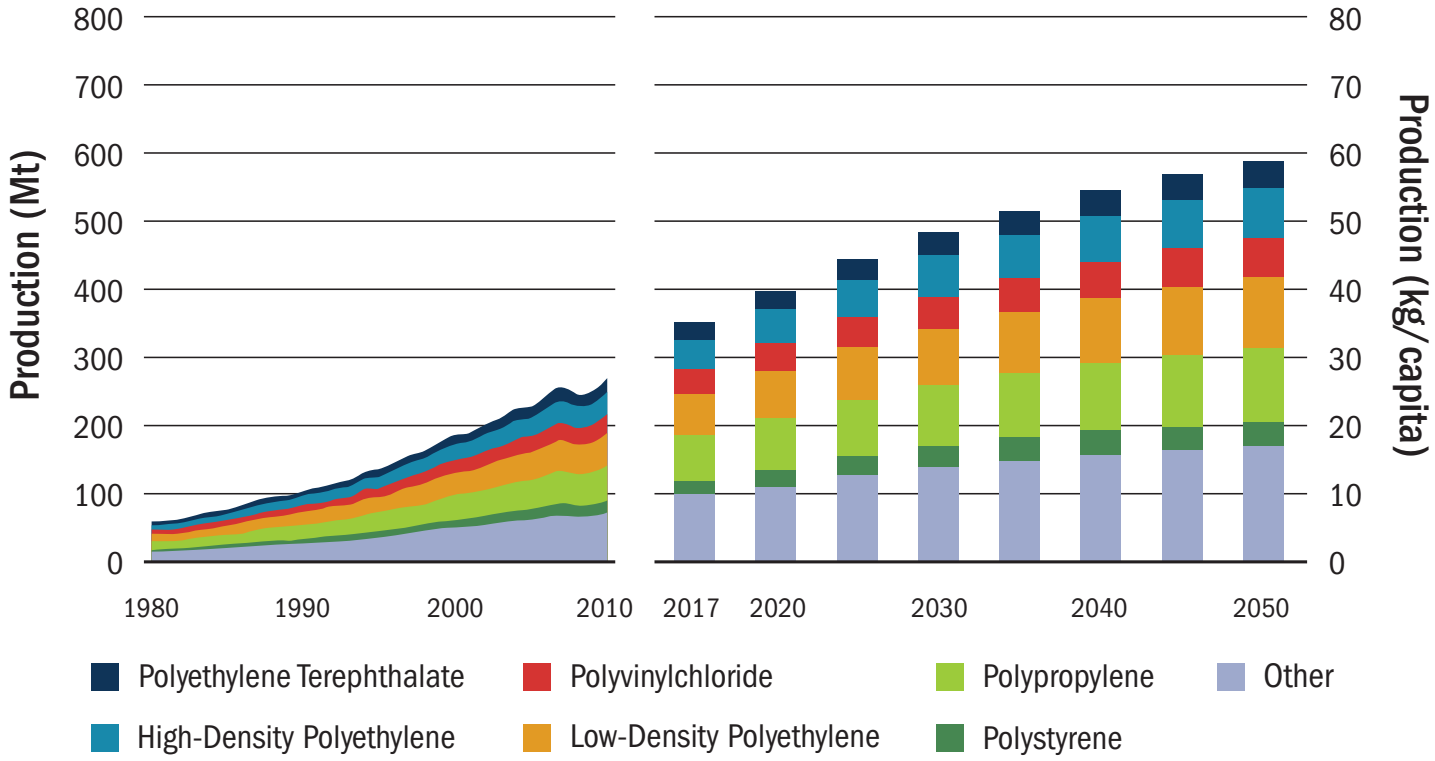
From basic research to technology deployment, the U.S. Department of Energy (DOE) supports research to revolutionize how plastic is created and recycled by mitigating waste, lowering GHG emissions, and reducing energy costs across the plastics sector. Through its Strategy for Plastics Innovation, DOE and its federal partners provide a blueprint for fostering a green plastics economy in which:

- Over 90% of commercial plastics can be recycled through cost-competitive technologies
- Recycling plastics saves more than 50% of processing energy relative to virgin plastic production
- More than 75% of the carbon in waste plastic is harnessed for further use
- Recycling methods reduce GHG emissions by at least 50% relative to virgin resin production.

DOE has a history in plastic waste management research, including bioprocesses to deconstruct plastics; chemical processes to upcycle plastic waste to higher value products; synthetic routes to convert carbon oxides to a plastic feedstock; and thermal deconstruction of plastic waste to valuable intermediate chemicals. This expertise positions DOE to set aggressive goals and metrics for coordinated research throughout the agency—uncovering and ultimately deploying new methods to deconstruct, upgrade, and repurpose plastic waste.

[1] energy.gov/quadrennial-technology-review-2015

Realized and Predicted Production of Commodity Plastics through 2050



Under business as usual, plastic production is expected to increase substantially through 2050. R&D to improve plastic recycling could unlock substantial energy efficiency and climate opportunities. *Figure courtesy of DOE.*

Today's Plastic Waste Challenges

The domestic plastics industry is responsible for roughly 2% of U.S. energy consumption and 3% of U.S. GHG emissions.[2] Commodity plastic waste is particularly challenging to process, which allows it to easily build up in the environment and break down into microplastics. Under a business-as-usual scenario, scientists estimate that by 2050 there will be more plastic in the ocean than fish by mass.[3] Pollution associated with plastics also disproportionately affects disadvantaged communities, which can impede environmental justice.[4]

Plastic waste is difficult to process largely because of the way many plastics are designed and produced. Plastics are often:

- Incompatible with one another
- Highly varied in chemical composition
- Chemically cross-linked, making them difficult to dissolve in a solvent or made to flow at elevated temperatures
- Filled with impurities and small molecule fillers, which are unknown or proprietary non-polymer components added to achieve desired properties.

Combined, these attributes limit sorting and processing options, complicating an already challenging recycling landscape.

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A Research Strategy to Rethink Plastic

DOE's Strategy for Plastics Innovation outlines approaches for addressing the challenge of plastic waste through improved recycling technology and infrastructure; innovative alternatives for reusing, or "upcycling," polymers; and scientific and technological solutions for repurposing these complex materials.

[2] doi.org/10.1016/j.joule.2020.12.027

[3] ellenmacarthurfoundation.org/the-new-plastics-economy-rethinking-the-future-of-plastics-and-catalysing

[4] unep.org/resources/report/neglected-environmental-justice-impacts-marine-litter-and-plastic-pollution

Three research thrusts are critical to meeting the goals of this effort:

- Thermal, chemical, and biological deconstruction and upgrading of plastics
- Enhancements to traditional mechanical recycling and sorting
- New, application-driven plastics and materials that are easily recyclable or degradable by design.

Through these diverse strategies, DOE advances new technologies that foster environmental justice, promote a clean plastics economy, and drastically reduce the amount of plastic produced from virgin feedstock. In this way, the strategy achieves multiple DOE and Biden Administration priorities.

Federal Agencies Work Collaboratively to Achieve the Goal

The scaffolding behind DOE's Strategy for Plastics Innovation was formed from numerous workshops, reports, and collaborations. DOE pooled expertise from across its offices—Energy Efficiency and Renewable Energy (EERE), Science (SC), Fossil Energy and Carbon Management (FECM), and Advanced Research Projects Agency–Energy—which will supply key expertise moving forward as new solutions are formulated.

As part of DOE's broader coordination, the core offices have released reports based on their expertise:

- EERE's Plastics for a Circular Economy[5]
- SC's Chemical Upcycling of Polymers[6]
- FECM's Strategic Vision.[7]

DOE has also collaborated externally to address the challenge of plastic waste, such as participating in the National Academy of Sciences workshop, "Closing the Loop on the Plastics Dilemma."[8] DOE also routinely partners with other government agencies, including the National Science Foundation, the National Institute of Standards and Technology, and the U.S. Environmental Protection Agency, as well as with foreign governments, including Australia and New Zealand.

Plastic waste is difficult to process because of the many varieties of plastics and various ways to design and produce them.
Photo courtesy of iStock 1096570546.

[5] energy.gov/sites/default/files/2023-01/DOE-strat-for-plastics-innova.pdf
[6] osti.gov/servlets/purl/1616517
[7] energy.gov/sites/prod/files/2020/08/f77/FE-20%20Strategic%20Vision%20FINAL%202020_Aug_12_compliant.pdf
[8] doi.org/10.17226/25647

DOE draws from deep expertise and a history in plastic waste management research, including ongoing experiments at DOE national laboratories across the country. *Photo courtesy of Dennis Schroeder, National Renewable Energy Laboratory 64102.*

Feedback and Funding Drives Plastic Strategy

DOE's Strategy for Plastics Innovation was developed through a rigorous review process that invited feedback from sectors with interests across the entire plastics recycling value chain. In January 2021, DOE released a draft strategy (originally titled "Roadmap") and executed a request for information from the public to bolster its plastics approach. In total, 43 industrial, academic, government, and advocacy groups responded—offering feedback that DOE incorporated into the final document.

The same year, DOE allocated $54.5 million toward plastic waste management and upcycling research. In line with DOE's goals of energy security and efficiency, this funding continues to support R&D that improves the value of plastic waste, reduces emissions and GHGs from plastics production, keeps plastics out of landfills and the environment, and decreases the plastic industry's dependence on fossil feedstocks. ■

About the Strategy for Plastics Innovation

The Strategy for Plastics Innovation will focus resources from across the U.S. Department of Energy to create a comprehensive program to accelerate innovations that will dramatically reduce plastic waste in oceans and landfills. It will also position the United States as a global leader in energy-efficient advanced plastics recycling technologies and in the manufacture of new plastics that are recyclable by design and have reduced greenhouse gas emissions. The Strategy for Plastics Innovation will draw on both fundamental and applied research capabilities within national laboratories, universities, and industry. Learn more: energy.gov/plastics-innovation.

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For more information, visit: energy.gov/plastics-innovation

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