

Industrial Innovation: Bioenergy Expands the Possible

To combat climate change, the United States leads by example to build a 100% clean energy economy and reach net-zero emissions by 2050. Innovations in the production and incorporation of everyday materials—like plastics and fuel—can make a big impact.

The U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) is driving research and development (R&D) on a wide range of technologies and manufacturing improvements that make biofuels and bioproducts cost competitive and effective at meeting the needs of people and businesses.¹

Current Infrastructure Supports Expansion of Bioenergy

The U.S. economy relies on dependable transportation to move goods and people. Motorists, airlines, shippers, and others in the transportation sector rely on the massive domestic and global fuel infrastructures that ensure each has the fuel they need when and where they need it. Existing U.S. fueling infrastructure, for example, provides more than 100,000 vehicle gas stations served by well-established regional refineries, fuel storage, and distribution networks.² These systems have been in place for decades and have been tested in times of crisis, natural disasters, trade disruptions, and even a global pandemic.



An algae-based flip-flop prototype made by Algenesis in their UCSD laboratory.
Photo courtesy of Daniel Fishman, BETO

Existing Fuel Refineries Support Solutions to Pandemic

As we look for cleaner fuel alternatives, biofuels can provide a compatible solution to this well-established and pressure-tested infrastructure. Through a range of initiatives, BETO is driving innovation in infrastructure to ultimately make biofuels more affordable and accessible.

In 2014, a joint venture between POET, LLC., the world's largest producer of biofuels, and Royal DSM, the multinational sustainable living company, developed the nation's first corn stover-fed advanced biofuels biorefinery with funding support from BETO. As COVID-19 created unprecedented demand for sanitation and cleaning products, POET was in a unique position to help fill this need. Their first-generation, grain-based ethanol refineries produced pharmaceutical-grade alcohol-based hand sanitizer and cleaning products.³

Bioproduct Innovations Revolutionize Industries

Plastics made from fossil fuels have been around for generations and are used in everything from bobsleds to

baby bottles. However, these plastics are not only made from fossil resources, but their production requires the release of additional greenhouse gases (GHG). BETO supports R&D to produce renewable plastics with dramatically reduced GHG emissions alongside fuels at an integrated biorefinery.

Bio-derived plastics have many of the same properties as traditional plastics and can be reused, recovered, and recycled with reduced GHG emissions.⁴

Yet converting biomass into biochemicals can be costly. BETO has funded research to develop cost-effective bioproduct solutions that help reduce GHGs and provide an extra revenue stream for existing biorefineries.⁵ This research includes:

- The development of advanced plastic recycling technologies, such as new methods for deconstructing and

New Foams Made Entirely from Algae Could Support Your Next Yoga Mat, Skateboard, or Mattress

Researchers at the University of California, San Diego (UCSD) have built on their success in developing products partially made from algae-based foam. In a new project supported by BETO, the team will work to develop **foams made from >80% renewable plant and algae feedstocks**. These foams can be modified to produce many household products, including yoga mats, insulation, mattresses, car molding, construction glues, and paint. These diverse products typically all have one thing in common: they're made from polyurethane, which comes from petroleum. Until recently, creating foams entirely from plants and algae was impractical, but researchers are making exciting progress toward changing that. This research enables U.S. industry to drive down costs for consumers and lower emissions for everyone.⁶

¹ energy.gov/eere/bioenergy/articles/broadening-participation-bioeconomy-through-small-business-partnerships

² [statista.com/statistics/525107/number-of-gasoline-stations-in-the-united-states](https://www.statista.com/statistics/525107/number-of-gasoline-stations-in-the-united-states)

³ energy.gov/eere/bioenergy/articles/beto-and-poet-dsm-biorefinery-pivots-support-covid-19-response

⁴ energy.gov/eere/articles/integrating-production-biofuels-and-bioproducts

⁵ energy.gov/eere/bioenergy/articles/nrel-recycles-biorefinery-waste-streams-create-high-value-chemical-products

⁶ energy.gov/eere/bioenergy/articles/new-foams-made-entirely-algae-could-support-your-next-yoga-mat-skateboard-or

upcycling existing plastics. Funding has also been announced for the development of new plastics that are recyclable-by-design, or biodegradable plastics. (Jointly funded by BETO and the Advanced Manufacturing Office).⁷

- The creation of a method to recycle biorefinery waste streams to create high-value chemical products—the precursors to everyday materials like plastics. (National Renewable Energy Laboratory).⁸

Manufacturing Advancements Lower Bioenergy Costs

In July 2021, DOE's Agile BioFoundry consortium announced the selection of eight Directed Funding Opportunity R&D projects totaling over \$5.2 million to accelerate the U.S. biomanufacturing sector. These projects allow companies to leverage Agile BioFoundry resources to accelerate R&D in industry. Projects include:

- Huue, of Oakland, CA, will improve production of biosynthetic indigo dye, a sustainable replacement for fossil-derived indigo.
- Industrial Microbes, of Alameda, CA will eliminate barriers to the use of gaseous feedstocks by creating a predictive model that identifies productivity improvements, forecasts performance, and enhances the robustness of gas fermentation processes.
- LanzaTech, of Skokie, IL, will expand the genetic engineering toolbox of the non-model organism *Clostridium spp.* in order to accelerate the discovery process of next-generation biofuels and chemicals.
- Levadura Biotechnology, of San Diego, CA, will work on efficient production of triacetic acid lactone, a precursor to several bio-based products.
- Technology Holding, of Salt Lake City, UT, will develop a bio-based replacement for adipic acid, a precursor of nylon, aiming to generate enough material for testing with partners in the fashion industry.
- TeselaGen Biotechnology, of San Francisco, CA, deploy artificial intelligence for community-generated data, saving resources and speeding up the biomanufacturing commercialization timeline.

Through the Fiscal Year 2021 Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, BETO aims to direct R&D resources to address challenges influencing access to bioenergy R&D and increase representation of those who participate in and benefit from the bioeconomy.⁹

A Cleaner Future Now with Bioenergy

Bioenergy is a critical part of a holistic approach to addressing the U.S. clean energy future with solutions that strengthen the economy across multiple industries. Existing infrastructure will support rapid deployment, and BETO partnerships are driving R&D efforts on a variety of technologies and manufacturing improvements that will enable bioenergy to meet the needs of both people and businesses. ■

About the Bioenergy Technologies Office

BETO supports research, development, and demonstration to enable the sustainable use of domestic biomass and waste resources for the production of biofuels and bioproducts. BETO's overall goals are designed to:

- Lower costs and reduce technology risks for production of biofuels and bioproducts
- Improve environmental benefits of bioenergy production
- Reduce greenhouse gas emissions from the transportation, industrial, and agricultural sectors to address the climate crisis
- Support the scale-up of sustainable, low-carbon biofuel production technologies
- Create economic opportunities and good-paying jobs in agriculture and manufacturing sectors.

Meeting these goals requires significant and rapid advances in technology development and innovation across the entire biomass-to-bioenergy supply chain.

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For more information, visit:
energy.gov/eere/bioenergy

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⁷ energy.gov/articles/us-department-energy-announces-27-million-plastics-recycling-research-and-development

⁸ energy.gov/eere/bioenergy/articles/nrel-recycles-biorefinery-waste-streams-create-high-value-chemical-products

⁹ energy.gov/eere/bioenergy/articles/broadening-participation-bioeconomy-through-small-business-partnerships