

Bioenergy Technologies Office: Building a Low- Carbon U.S. Bioeconomy

The Bioenergy Technologies Office (BETO)—a program office within the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy—supports the research, development, and demonstration (RD&D) of technologies that mobilize renewable carbon resources across the U.S. economy. Including a variety of biomass and wastes, renewable carbon resources can be converted into sustainable, high-performance fuels as well as renewable chemicals and materials while lowering greenhouse gas (GHG) emissions.

BETO Research Helps Lower Emissions, Create Jobs, and More

The United States has a wealth of sustainable biomass and waste resources capable of supporting a robust bioeconomy. Every year, these renewable carbon resources can be leveraged to produce 50 billion gallons of low-carbon biofuels for aviation, ships, and heavy-duty vehicles; 75 billion kilowatt-hours of renewable electricity; and 17 billion pounds of bio-based commodities and products.¹



BETO's programs span the full bioenergy value chain—providing insights on resource harvesting, preprocessing, conversion, and transformation into sustainable high-performance fuels and products. *Photos from Werner Slocum, Dennis Schroeder, NREL, and Getty Images*

Those numbers can translate into substantial reductions in climate-warming GHGs—on the order of 450 million metric tons of carbon dioxide every year.² In this way, sustainable biofuels and bioproducts are essential in efforts to decarbonize key sectors of the U.S. economy, from the transportation and industrial sectors to the agricultural and power sectors.

Through strategic RD&D, BETO fosters the widespread adoption of bioenergy technologies that transform sustainable resources into equitable, affordable energy solutions. This can promote important environmental, social, and economic benefits:

- **Economic Growth:** Develop bioenergy and bioproducts to increase activity across the entire economy—reducing waste, creating new jobs in rural America, and growing construction and manufacturing.
- **National Opportunity:** Invest in new bioenergy technologies to help secure U.S. competitive advantage and enable private sector opportunities in renewable energy.
- **Renewable Resources:** To reduce GHG emissions, displace finite carbon resources (e.g., petroleum

and coal) with renewable carbon resources in everyday American products, such as gasoline, plastics, and industrial commodities.

The Strategy: De-Risking Bioenergy Technologies to Accelerate Market Adoption

BETO's strategy supports RD&D, analysis, and integration of bioenergy technologies to de-risk market adoption.³ With increasing interest in sustainable aviation and marine fuels, BETO emphasizes priority biofuels throughout its programs. BETO funds RD&D projects that can mobilize and efficiently convert domestic renewable carbon resources into biofuels and bioproducts to reduce GHG emissions across the U.S. economy.

To advance its strategic goals, BETO funds projects led by DOE national laboratories, universities, and industry. Some projects support lab-scale experiments in fundamental science.

BETO Mission

Develop and demonstrate technologies to accelerate GHG emissions reductions through the cost-effective, sustainable use of biomass and waste feedstocks across the U.S. economy.

¹ energy.gov/eere/bioenergy/downloads/2016-billion-ton-report-advancing-domestic-resources-thriving-bioeconomy

² doi.org/10.1002/bbb.1728

³ energy.gov/eere/bioenergy/articles/2023-multi-year-program-plan

BETO Strategic Goals

- **Decarbonize the transportation sector** through RD&D to produce cost-effective, sustainable aviation and other strategic fuels.
- **Decarbonize the industrial sector** through RD&D to produce cost-effective and sustainable chemicals, materials, and processes made from biomass and waste resources.
- **Decarbonize agriculture, generate carbon-negative power, develop carbon drawdown strategies, and harness other beneficial uses** by developing cost-effective, sustainable biomass and waste utilization technologies and innovative approaches.

Other projects demonstrate full facilities capable of producing large volumes of liquid biofuels and bioproducts—the final step before commercialization. BETO RD&D spans the full value chain—providing insights on resource harvesting, preprocessing, conversion, and finally transformation into sustainable high-performance fuels, materials, and products. BETO organizes its RD&D activities into four subprograms:

- Renewable Carbon Resources
- Conversion Technologies
- Systems Development and Integration
- Data, Modeling, and Analysis.

Renewable Carbon Resources

BETO's Renewable Carbon Resources subprogram develops strategies and supports technology development to mobilize renewable carbon resources to enable the production of bioenergy and bioproducts. The subprogram focuses on facilitating availability, reducing cost, improving quality, and maximizing environmental benefits. Renewable carbon resources include:

- Agricultural residues (e.g., corn stover)
- Forestry residues (e.g., forest thinning)
- Purpose-grown energy crops (e.g., algae, switchgrass)
- Seaweed
- Waste streams (e.g., municipal solid waste)
- Resources from ecosystem restoration or maintenance (e.g., salvaged material from natural disasters)
- Commodity crops (e.g., oil seed crops).

Biomass

A resource derived from plant- and algae-based material. It includes agricultural residues, forest residues, woody and herbaceous energy crops, and algae.

Waste

A resource including wet waste (e.g., biosolids), non-recycled municipal solid waste, urban wood waste, food waste, biogas, and industrial waste gases.

BETO RD&D optimizes the use of each unique resource alongside a range of important sustainability factors: land-use change, GHG emissions, biodiversity, impact on food security, impact on communities, and more. Mobilizing this wide range of carbon resources most responsibly and efficiently takes close coordination with stakeholders and many other federal offices and agencies. Furthermore, BETO's strategic RD&D approach outlines how renewable carbon resources are produced, sourced, processed, and stored to ensure a reliable, consistent feedstock supply for biorefineries.

Conversion

BETO's conversion program supports RD&D on technologies for converting biomass feedstocks into finished liquid transportation fuels such as renewable gasoline, renewable diesel, and sustainable aviation fuel. BETO is exploring a variety of conversion technologies that can be combined into pathways, from feedstock to product. BETO funds projects that target barriers in critical conversion process steps—with a goal of empowering companies with data and experimentally verified technologies.



Low-carbon biofuels like sustainable aviation fuel are essential in efforts to decarbonize key sectors of the U.S. economy. *Photo from Getty Images*

BETO conversion process steps are roughly divided into two categories:

1. Deconstruction and Fractionation:

Breaking down feedstocks into upgradable intermediates.

Example processes:

- ✓ Gasification breaks down biomass particles into synthesis gas
- ✓ Pyrolysis breaks down feedstock into a bio-oil intermediate
- ✓ Pretreatment and hydrolysis deconstruct biomass into simple sugars and other carbohydrate intermediates.

2. Synthesis and Upgrading:

Converting intermediates into useful end products.

Example products:

- ✓ Finished fuels
- ✓ Fuel precursors
- ✓ High-quality intermediates like sugars, synthesis gas (syngas), or stabilized bio-oils
- ✓ Bio-based chemicals or products.

The diversity of feedstocks, intermediates, and end products requires a variety of conversion technologies.

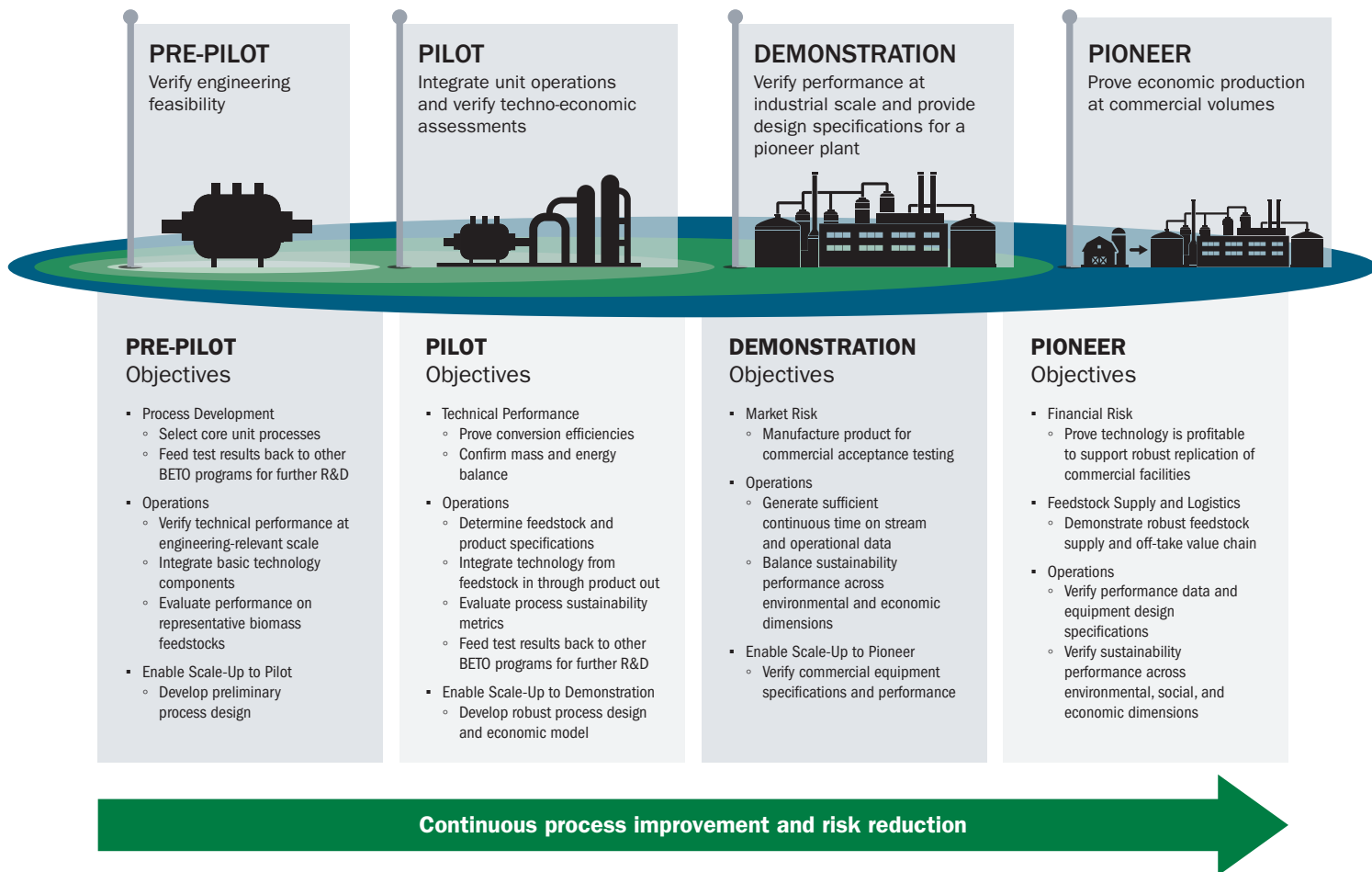
Systems Development and Integration

BETO’s systems development and integration program develops, tests, and verifies pre-pilot-, pilot-, and demonstration-scale biorefinery

performance. The program’s purpose is to reduce technology uncertainty and enable industry to lead scale-up projects that accelerate commercialization. Although industry may target an assortment of marketable products, BETO invests in technologies aimed at decarbonizing energy-intensive sectors of the economy.

Projects include:

- Combining technology components, unit operations, or subsystems
- Testing processes as integrated operations
- Conducting downstream tests of fuel production
- Verifying the integrated process at various scales.



Verifying technologies at appropriate partially or fully integrated scales is important to reducing technology uncertainty and overcoming operational challenges. *Figure from NREL*

Data, Modeling, and Analysis

BETO supports RD&D that explores affordable, reliable, and environmentally sustainable bioenergy technologies. This includes research into whether technologies are cost effective, protect natural resources, and enhance and equitably distribute economic, environmental, and social benefits.

BETO's data, modeling, and analysis program supports research, analysis, and tool development to help illuminate these complexities. The program also supports researchers and decision makers as they work to pinpoint the highest value fuels and products with the biggest potential for lowering GHG emissions.

Key BETO analyses include:

- **Technology-Specific Analyses:** Explore sensitivities and identify areas where BETO investment may lead to the greatest impacts as well as outline R&D needed to develop emerging ideas.
- **System-Level Analyses:** Inform strategic direction and planning efforts to help BETO focus its technology development priorities and identify key drivers and hurdles for maximum national impact. ■



BETO's data, modeling, and analysis program supports research, analysis, and tool development to illuminate the complexities of commercializing bioenergy technologies in the real world. *Photo by Werner Slocum, NREL*

About the Bioenergy Technologies Office

BETO supports RD&D to enable biofuel innovations for the United States to remain competitive today while ensuring a clean energy future. BETO's overall goals are designed to:

- Develop a viable, sustainable domestic biomass industry that produces renewable biofuels, bioproducts, and biopower
- Provide environmental benefits
- Create nationwide economic opportunities.

Meeting these goals requires significant and rapid advances in the entire biomass-to-bioenergy supply chain—from nature to consumer.

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

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