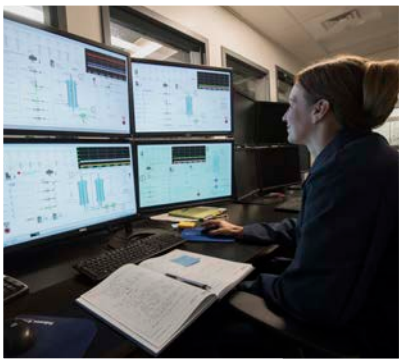
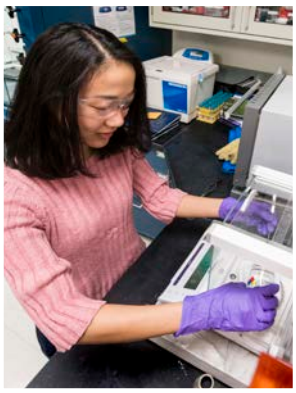
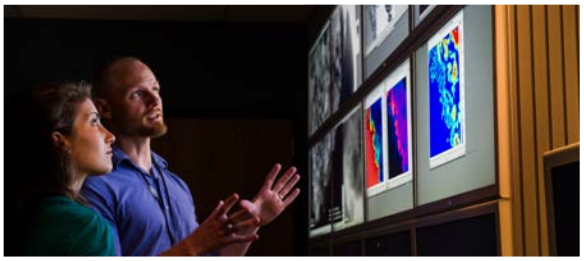
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY





Bioenergy Technologies Office: Growing America's Energy Future

The U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy's Bioenergy Technologies Office (BETO) supports groundbreaking technologies to produce fuels, products, and power from non-food sources of biomass and waste resources. Bioenergy can help ensure an economically sound and secure future while reducing environmental impacts through:

- Developing affordable domestic fuels and co-products
- Advancing clean energy sources
- Generating domestic jobs to support the growth of the U.S. bioeconomy.

The Benefits of BETO R&D

Biomass and waste streams are examples of renewable sources that can supplement petroleum-based liquid transportation fuels—such as gasoline, jet, and diesel fuel—in the near- to mid-term. These can be used to produce valuable chemicals for manufacturing and to supply power for the U.S. electrical grid.

BETO focuses on forming public-private partnerships to support research and development (R&D) for the production of industrially viable bioenergy and bioproducts using renewable biomass and waste streams. BETO guides R&D efforts at the DOE National Laboratories to produce "drop-in" biofuels compatible with existing fueling infrastructure and vehicles.

BETO works to reduce technological uncertainty in order to attract commercial investment for biomass feedstock supply systems, conversion processes, and integrated biorefineries. Success depends on the following factors:

- Rapid development of efficient new systems and networks to reliably produce, harvest, and supply large quantities of diverse biomass waste feedstocks without negative impacts to the environment
- Advanced technologies to cost-effectively convert biomass and waste to biofuels, bioproducts, and biopower
- Engineering to support the integration of process steps and subsequent scale-up of pilot, demonstration, and pioneer commercial plants that reliably and economically produce biofuels and bioproducts.

BETO Mission

To develop industrially relevant, transformative, and revolutionary bioenergy technologies to enable sustainable, domestically produced biofuels, bioproducts, and biopower for a prosperous nation.

BETO Strategic Goal

To enable use of America's abundant biomass and waste resources for biofuels, bioproducts, and biopower by:

- Identifying and developing biofuel pathways and innovative end uses
- Lowering the cost of production through increased efficiency, productivity, and yields
- Completing applied R&D on complex, real-world systems
- Integrating engineering processes for promising new advanced bioenergy technologies
- Maintaining or enhancing economic and environmental impacts.

Strategic Approach

BETO funds work in collaboration with industry, academia, and DOE National Laboratories to develop advanced technologies and innovative solutions to reduce costs. The R&D supported by BETO and its partners is creating cutting-edge technologies used in the processing of biomass and waste, from harvesting and preprocessing to conversion. BETO is focused on technologies to efficiently convert organic materials and non-food biomass into affordable biofuels and bioproducts.

The following five program areas, highlighted in greater detail below, enable BETO to leverage diverse sources of biomass and waste across America and use innovative technologies to enable a thriving bioeconomy grounded in achieving national priorities for economic growth and job creation:

- Feedstock Supply and Logistics
- Advanced Algal Systems
- Conversion
- Advanced Development and Optimization
- Sustainability and Strategic Analysis.

Feedstock Supply and Logistics

The Feedstock Supply and Logistics R&D program focuses on developing technologies to provide a reliable, affordable, and sustainable supply of carbon, such as terrestrial biomass waste streams, and process these into dependable feedstock sources. Examples of renewable biomass and waste streams include:

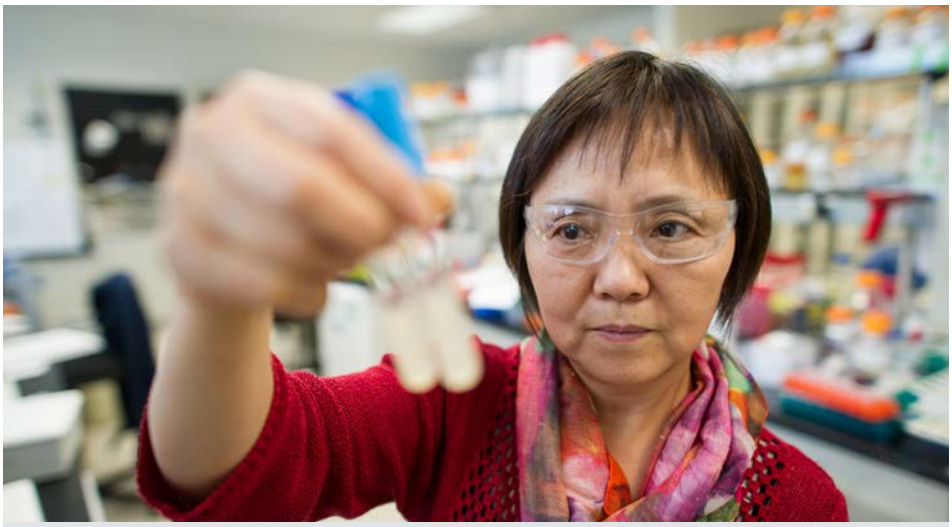
- Agricultural residues (e.g., corn stover and wheat straw)
- Energy crops (e.g., switchgrass, miscanthus, energy cane, sorghum, hybrid poplars, and shrub willows)
- Forest residues (e.g. tops and branch trimmings)
- Industrial and other wastes (e.g., sorted municipal solid waste, food waste, and biosolids and sludges).

All aspects of the supply chain—from crop production to transport storage systems, and processing —must be addressed in order to reduce the cost, improve the quality, and increase the volume of reliable and environmentally beneficial feedstocks available to a biorefinery. This program area works to identify both present and future terrestrial feedstock supply and logistics.

Feedstock supply involves developing a diverse variety of feedstocks used to produce energy and products. BETO engages in research to assess all potential biomass resources while considering such factors as cost, quality, and environmental impact. This research allows BETO to select cost-effective feedstock supply projects for development and subsequent demonstration by industry.

Bioenergy researchers at work in a fermentation lab. *Photo by NREL.*

Feedstock logistics encompass all the operations needed to collect, preprocess, and transport feedstocks to a biorefinery for optimal conversion into biofuels and bioproducts while maintaining necessary quality standards. R&D aims to improve the quality, productivity, and costs for the harvesting and processing of feedstocks.



A scientist examines test tubes growing Zymomonas cells in the laboratory. *Photo by NREL.*

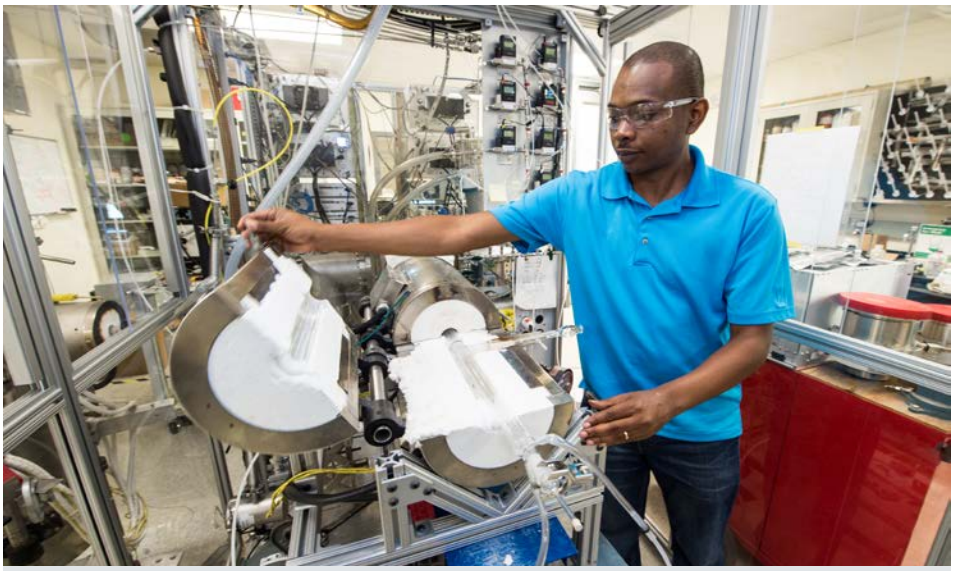
Advanced Algal Systems

Algal feedstocks can contribute to expanding domestic advanced biofuel and bioproduct resource potential. Algal biomass includes microalgae and macroalgae as well as cyanobacteria. Algal biofuel and bioproduct intermediates include:

- Extracted lipids
- Products derived from sugars or proteins (alcohol or hydrocarbon fuels)
- Secreted metabolites (alcohols or other molecules)
- Biocrude resulting from hydrothermal liquefaction.

These intermediate products must be upgraded and/or blended and/or purified to produce a finished fuel or bioproduct.

The Advanced Algal Systems R&D program focuses on two areas—algal biomass supply and logistics. Algal biomass supply includes resource assessment, algal strain improvement, and development of efficient cultivation systems to increase productivity. Algal logistics include reducing costs and improving efficiencies of harvest/dewatering and sustainable intermediate production and stabilization. Developing algal feedstocks to achieve BETO's advanced biofuel price goals requires breakthroughs along the entire algal biomass supply chain.



A researcher works with a molecular beam mass spectrometer. *Photo by NREL.*

Conversion

The Conversion R&D program develops technologies to convert non-food feedstocks into biofuels, bioproducts, and biopower. Biomass conversion involves the deconstruction and fractionation of feedstocks into intermediate streams such as sugars, bio-oils, gaseous mixtures, and chemical building blocks. These intermediates are then synthesized and upgraded into commercially viable products.

Deconstruction and fractionation begins with processing using a variety of conversion technologies that can address the physical and chemical characteristics of various biomass and waste-derived feedstocks. Deconstruction processes take place either at high or low temperatures. High-temperature deconstruction processes include:

- Pyrolysis, which produces a bio-oil intermediate
- Hydrothermal liquefaction that is applicable to algal feedstocks, as well as a wide range of other wet feedstocks, which produces a specific type of bio-oil
- Gasification, which produces a synthesis gas (syngas).

Low-temperature deconstruction begins with the breakdown of feedstock into intermediates by pretreatment that uses chemical or mechanical processing to separate the feedstock into soluble and insoluble components, thus producing sugar polymers and other components. The low-temperature pretreatment is followed by hydrolysis that uses enzymes or chemicals to break down the feedstock polymers into their component sugar units and/or aromatic monomers.

Synthesis and upgrading incorporates various techniques to produce a finished product from intermediate streams and chemical building blocks. Intermediates can be sold into the market to be used in a petroleum refinery, chemical

Biomass

Biomass is an energy resource derived from plant- and algal-based materials or organic waste streams. It includes agricultural residues, forest resources, perennial grasses, woody energy crops, algae, wet wastes (e.g., biosolids), sorted municipal solid waste, urban wood waste, food waste, biogas, and other waste streams. Biomass and waste are valuable carbon resources as they can be converted to fuels, chemicals, or power and may address the additional problem of utilizing carbon for a second time.

Bioeconomy

The bioeconomy refers to a global transition to the sustainable use of renewable biomass resources in energy and products leading to economic, environmental, and national security benefits.

A scientist cultivates microorganisms for the production of renewable fuels.
Photo by NREL.

manufacturing plant, or biorefinery. These techniques may include:

- Biological processing that utilizes microorganisms to convert sugar or gaseous intermediates into fuel blendstocks and chemicals
- Catalytic processing and stabilization to minimize the effect of intrinsic reactive compounds and thus improve storage and handling properties of intermediate streams, such as sugars, bio-oil, and syngas and convert the intermediate streams into fuel stocks and chemicals

After upgrading, final product streams must conform to standards for commercial off-take agreements.

Advanced Development and Optimization

Developing a bioeconomy requires integrated biorefineries capable of efficiently converting a broad range of biomass and waste stream-derived feedstocks into affordable biofuels and co-products. The Advanced Development and Optimization program aims to reduce technology uncertainty in integrated bioenergy production processes that are scalable.

In partnership with industry, the Advanced Development and Optimization program works to develop, build, and operate integrated biorefineries at the pilot and demonstration scales to enable industry and loan programs to proceed to the pioneer commercial scales. These public-private partnerships are essential to proving the viability of various feedstock-conversion pathways and verifying integrated biorefinery systems' proof of performance, which may reduce investors' concerns with new technology viability and reliability. By creating a pathway to commercialization, the Advanced Development and Optimization program helps address the very high risk and uneconomical rigorous verification of pilot- and demonstration-scale technologies, which are vital steps to full-scale deployment that industry is averse to pursuing alone.

Sustainability and Strategic Analysis

The existing and emerging bioenergy industry will need to invest in systems based on economic viability, as well as environmental aspects, such as resource resilience and seeking to ensure no negative impacts.

The Sustainability and Strategic Analysis program focuses on developing resources, technologies, and systems to support the long-term viability of advanced bioenergy systems. This cross-cutting area is critical to achieving BETO's overall goals and national priorities.

The program collaborates with other government agencies and diverse stakeholders to develop and promote practices and technologies that enhance the benefits of bioenergy production activities while mitigating environmental and economic concerns. This work serves to:

- Promote economic development
- Maintain the benefits and services provided by natural resources
- Provide conditions that support human and societal health.

Bioenergy Industry Creates Jobs

A robust bioenergy industry will generate a variety of U.S. jobs across several sectors, from farming and trucking to microbiology and chemical engineering. Bioenergy and bioproduct production has significant potential to serve as a vehicle for domestic job creation and economic opportunity for communities throughout the nation. ■

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For more information, visit:
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