GROWING AMERICA'S ENERGY FUTURE

The emerging U.S. bioenergy industry provides a secure and growing supply of transportation fuels, biopower, and bioproducts produced from a range of abundant, renewable biomass resources.

Bioenergy can help ensure a secure, sustainable, and economically sound future by reducing U.S. dependence on foreign oil, developing domestic clean energy sources, and generating domestic green jobs. Bioenergy can also help address growing concerns about climate change by reducing greenhouse gas emissions to create a healthier environment for current and future generations.

Biomass is the only renewable energy source that can offer a viable substitute for petroleum-based liquid transportation fuels—such as gasoline, jet, and diesel fuel—in the near term. It can also be used to produce valuable chemicals for manufacturing, as well as to supply power for our electrical grid.

The Energy Independence and Security Act of 2007 set aggressive goals to reduce greenhouse gas emissions and our dependence on fossil fuels through increased production of biofuels. As part of the Act, the Renewable Fuel Standard requires the United States to produce 36 billion gallons of renewable fuels by 2022.

Meeting the Renewable Fuel Standard will require technological innovation, private investment, and clear government support for the domestic biofuels industry. The current challenge in bioenergy development is to efficiently convert algae and cellulosic biomass into renewable fuels that are compatible with today's vehicles and infrastructure.

Biomass

Biomass is an energy resource derived from plant-, algal-, and waste-based materials that include agricultural and forest residues, perennial grasses, woody energy crops, algae, wet waste (e.g., biosolids), sorted municipal solid waste, urban wood waste, and food waste. It is unique among renewable energy resources in that it can be converted to carbon-based fuels, chemicals, or power.

BETO Vision & Mission

BETO envisions a thriving and sustainable bioeconomy fueled by innovative technologies. BETO's mission is to develop and demonstrate transformative and revolutionary bioenergy technologies for a sustainable nation.

The Bioenergy Technologies Office (BETO), within the Office of Energy Efficiency and Renewable Energy of the U.S. Department of Energy (DOE), is focused on forming public-private partnerships to research, develop, and demonstrate technologies to produce commercially viable bioenergy and bioproducts.

BETO works to reduce technological risks in order to attract commercial investment for biomass feedstock supply systems, conversion equipment, and integrated biorefineries. Success will depend on the following factors: (1) rapid development of efficient new systems and networks to sustainably produce, harvest, and transport large quantities of diverse feedstocks; (2) advanced technologies to cost-effectively convert biomass to biofuels; (3) engineering to support the scale-up of pilot, demonstration, and pioneer operations that reliably produce biofuels and bioproducts; and (4) expanded and improved infrastructure to deliver these advanced biofuels to consumers across the United States.

Strategic Approach

BETO partners with industry, academia, and national laboratories to develop advanced technologies and real-world solutions to reduce costs and spur bioenergy market growth. The advanced research, development, and demonstration (RD&D) supported by BETO and its partners is leading to the commercialization of cutting-edge technologies used in the processing of biomass, from harvesting to preprocessing to conversion. BETO is focused on developing technologies to efficiently convert plant-based, non-food biomass into biofuels and bioproducts that can directly replace those created from petroleum. BETO applies a coordinated approach prioritizing advanced RD&D projects based on systematically investigating, evaluating, and verifying the most promising opportunities across a wide range of emerging technologies. This approach leads to a balanced technology portfolio, which supports applied research and scales the most promising technology pathways from pilot plants to demonstration-scale biorefineries.

The following five critical program areas within BETO, highlighted in greater detail below, enable BETO to leverage the diverse sources of biomass and innovative technologies while also helping to develop a thriving bioeconomy grounded in achieving national priorities for economic growth and job creation:

- Terrestrial Feedstock Supply and Logistics
- Advanced Algal Systems
- Conversion
- Demonstration and Market Transformation
- Sustainability.

Terrestrial Feedstock Supply and Logistics

The Terrestrial Feedstock Supply and Logistics research and development program focuses on developing technologies to provide a reliable, affordable, and sustainable supply of terrestrial biomass feedstock sources, such as agricultural residues (e.g., corn stover); energy crops (e.g., switchgrass, miscanthus, energy cane, sorghum, hybrid poplars, and shrub willows); forest residues; industrial and other wastes (e.g., sorted municipal solid waste, food waste, and biosolids and sludges); and algae. All pieces of the supply chain—from plant breeding and crop production to transport and storage systems—must be addressed in order to reduce the cost, improve the quality, and increase the volume of sustainable feedstock available for delivery to a biorefinery. This program area works to identify both present and future terrestrial feedstock supply and feedstock logistics.

Feedstock supply involves developing a variety of feedstocks that can be used to produce energy and biobased products. BETO engages in rigorous research to assess all potential biomass resources, while considering such factors as sustainability, cost, and environmental impact. This research allows BETO to select cost-effective feedstock supply projects for development and demonstration.

Feedstock logistics encompass all of the operations needed to collect, preprocess, and transport feedstocks to a biorefinery for conversion into biofuel, while maintaining necessary quality standards. Research and development aims to improve the quality, productivity, and costs for the harvest and transport of feedstock.

Advanced Algal Systems

Algal feedstocks can contribute significantly to expanding domestic, advanced biofuel 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 others), or bio-crude 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 research and development 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.

Conversion

The Conversion research and development 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 preprocessing using a variety of conversion technologies that can address the physical and chemical characteristics of various biomass feedstocks. Deconstruction processes then take place either at a high or low temperature. High-temperature deconstruction processes include (1) pyrolysis, which produces a bio-oil intermediate, (2) hydrothermal liquefaction, which produces a specific type of bio-oil that is applicable to algal feedstocks, as well as a wide range of other feedstocks, and (3) gasification, which produces a synthesis gas (syngas). Low-temperature deconstruction begins with the breakdown of feedstock into intermediates by pretreatment, which uses chemical or mechanical processing to separate the feedstock into soluble and insoluble components, thus revealing sugar polymers and other components. The low-temperature pretreatment is followed by hydrolysis, which uses enzymes or chemicals to break down the feedstock polymers into their component sugars and/or aromatic monomers.

Synthesis and upgrading incorporates various techniques to produce a finished product—either to be sold into the commercial market or to be used in a petroleum refinery or chemical manufacturing plant—from feedstock intermediate streams.

These techniques may include (1) biological processing, which utilizes microorganisms to convert sugar or gaseous intermediates into fuel blendstocks and chemicals; (2) catalytic processing and stabilization to minimize the effect of reactive compounds and thus improve storage and handling properties of intermediate streams such as sugars, bio-oil, and syngas; and (3) intermediate upgrading to transform intermediate streams into crude product streams using biological or chemical processing, depending upon the stream.

After upgrading, final product streams must conform to standards for commercial off-take agreements. The fuel or product finishing may involve removing contaminant compounds and other processes to attain correct product specifications.

Demonstration and Market Transformation

Developing a bioeconomy requires integrated biorefineries capable of efficiently converting a broad range of biomass feedstocks into affordable biofuels. The Demonstration and Market Transformation program aims to reduce investment risk in bioenergy production technologies.

In partnership with industry, the Demonstration and Market Transformation program works to develop, build, and operate integrated biorefineries at the pilot, demonstration, and pioneer scales. These public-private partnerships are essential to proving the viability of various feedstock-conversion pathways and validating integrated biorefinery systems' proof of performance, which may reduce commercial financing barriers that currently face the bioenergy industry. By creating a pathway to commercialization, the Demonstration and Market Transformation program helps address the final links of the bioenergy supply chain and enables demand for end products.

Sustainability

The existing and emerging bioenergy industry will need to invest in systems based on economic viability and market needs, as well as environmental and social aspects, such as resource availability and public acceptance.

The Sustainability Program focuses on developing resources, technologies, and systems to support the long-term viability of advanced bioenergy systems. This area is critical to achieving BETO's overall goals and national priorities as defined in Executive Order 13514, "Federal Leadership in Environmental, Energy, and Economic Performance."

The sustainability area develops and applies scientific approaches to quantify bioenergy sustainability and 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, economic, and social concerns. This work serves to maintain the benefits and services provided by natural resources, promote economic development, and provide conditions that support human and societal health.

Bioenergy Industry Creates Green Jobs

A robust bioenergy industry will generate a variety of U.S. jobs across several sectors, from farming and trucking to biochemical engineering and microbiology. Employment in the biofuels industry has grown by 147% since 2005.[1] Ethanol production, construction, and research supported the creation of more than 357,400 jobs across the economy in 2015.[2] Combined spending for ethanol operations, research, and agriculture in 2015 added nearly $44 billion to the nation's gross domestic product.[3] The broader bioenergy industry is projected to stimulate significant job growth in the future, and nearly 2 million new jobs could be added across the economy in the next 9–15 years.[4]

[1] *Celebrating Ten Years of the Renewable Fuel Standard*, Renewable Fuels Association, August 6, 2015.

[2] John M. Urbanchuk, *Contribution of the Ethanol Industry to the Economy of the United States in 2015*, Renewable Fuels Association, February 5, 2016.

[3] John M. Urbanchuk, *Contribution of the Ethanol Industry to the Economy of the United States in 2015*, Renewable Fuels Association, February 5, 2016.

[4] *U.S. Economic Impact of Advanced Biofuels Production: Perspectives to 2030*, Bio Economic Research Associates, February 2009.

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