The National Bioenergy Center
Laying the Foundation for Biorefineries

Biomass
Sustainable Fuels, Chemicals, Materials, and Power

Biomass Program—Sustainable Fuels, Chemicals, Materials, and Power

National Bioenergy Center Expertise —25 Years of Biomass R&D

Agricultural
- Agricultural Engineering
- Agricultural Economics
- Harvesting Technology
- Forestry

Biological
- Biochemistry
- Applied Microbiology
- Molecular Biology
- Genomics
- Genetics
- Ecology

Chemical
- Biomass Characterization
- Analytical Chemistry
- Catalysis
- Organic Synthesis
- Wood Chemistry and Products

Engineering and Analyisis
- Biochemical Engineering
- Chemical Engineering
- Process Engineering
- Mechanical Engineering
- Separations
- Resource Assessment
- Systems and Life-Cycle Analysis

Strategic Partnerships —We Want to Work With You
- Food Products Industry
- Forest Products Industry
- Chemical & Petroleum Refining Industries
- Transportation Fuels Industry
- Biotechnology Industries
- Other DOE Laboratories
- U.S. Department of Agriculture
- EPA and Other Federal Agencies
- Academic and Research Community
- State and Local Governments

The 20th century was the century of the petrochemical economy. Biomass-derived fuels, chemicals, power, and materials will make the 21st century one in which domestic farmers and foresters help fuel as well as feed and house America. Advanced biomass conversion technology will play a major role in eliminating the need for imported oil and the generation of greenhouse gases from burning fossil fuels. As the only renewable source of carbon-based fuels and chemicals, biomass will be a critical component in reducing oil imports and environmental burdens from relying on fossil resources for fuels and chemicals. The U.S. Department of Energy (DOE) is supporting technology development for biorefineries and other biomass conversion industries and the National Bioenergy Center (NBC) is the focal point for research to make this technology possible.

DOE established the NBC in October 2000. The NBC has primary responsibility for carrying out the agenda of the Office of the Biomass Program of the Office of Energy Efficiency and Renewable Energy (EERE) of DOE and also supports related EERE and Office of Science programs. The National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL), Idaho National Engineering and Environmental Laboratory (INEEL), and Pacific Northwest National Laboratory (PNNL) all contribute to NBC efforts. Collaborating with industrial and academic—as well as other governmental—research, development, and commercialization organizations is vital to the NBC mission. The technologies, capabilities, and facilities described below are all available to industry for research and development collaborations to foster development of biomass conversion technology and biorefineries.

Jim Yost Photography/PIX 12688

To aid analysis of the effectiveness of biomass conversion technologies, National Bioenergy Center researchers use highly sophisticated equipment such as molecular-beam mass spectrometers and this liquid chromatograph mass spectrometer.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

The mission of the National Bioenergy Center is to foster capability building in renewable bio-based fuels, chemicals, industrial products, and power to catalyze the creation of new industries and support technical improvements in efficient and economical use of biomass in agriculture- and forest-based industries.

Biomass Production and Conversion Technologies

From their research and development (R&D) of biomass growth and conversion technologies, NBC researchers have developed proven expertise on most aspects of biomass processing and analysis.

Biomass Growth and Collection: NBC researchers at ORNL have long led the way in developing fast-growing trees and grasses as potential dedicated energy crops. They are now teaming up with INEEL to develop more efficient and cost-effective systems to supply agricultural residues. NBC researchers at INEEL are investigating the entire supply chain, including residue collection, storage, and transportation. This, includes developing technologies for "single-pass" harvesting of both grain and stover or straw. ORNL researchers with joint appointments at the University of Tennessee have access to university biosystems, engineering laboratories, and farms for doing research on agricultural machinery and feedstock preprocessing. ORNL facilities supporting plant sciences research include land and greenhouses, as well as plant physiology and genome-sequencing laboratories.

Pretreatment: While the NBC has focused mostly on dilute-acid pretreatment of cellulosic biomass, NBC researchers have investigated other technologies and coordinated DOE support of research on several of them. The NBC also coordinates and is very active in a consortium of leading researchers establishing standards for pretreatment research.

Enzymatic Hydrolysis: NBC researchers are leaders in understanding the fundamental science behind cellulose hydrolysis and they are recognized experts in the improvement and use of cellulases. NBC analysts determined that with lower-cost cellulase enzymes, enzymatic hydrolysis would be the most cost-effective way to hydrolyze cellulose and that reducing the cost of cellulases has the greatest potential for reducing the overall cost of biomass processing. To marry its own research with the experience of industry, the NBC is therefore also managing major DOE contracts with the world's largest enzyme companies to reduce cellulase cost. This collaboration is expected to provide a major boost to making cellulosic ethanol cost competitive.

Fermentation: NBC scientists have developed award-winning bacterial strains for selectively fermenting pentose/hexose mixtures to ethanol and for producing high yields of succinic acid. The NBC is well recognized for its ability to rigorously evaluate improved fermentation strains, enzymes, and technologies for biomass processing. Sophisticated protein synthesis and analysis equipment and capabilities are also available through ANL and ORNL.

Gasification: The NBC is at the forefront of applying gasification technology to biomass. From a utility in Vermont using waste wood to generate electricity, to electrification of remote villages in the Philippines, the NBC has played key roles in the first commercial applications of biomass gasification both at the small-modular-generator and the large-power-plant scales. NBC expertise in gas cleanup and catalytic conditioning has made major contributions to biomass gasification technology.

Pyrolysis: The NBC has extensive experience with pyrolysis processing, having developed technologies for producing chemicals from biomass and for recovering and regenerating base polymers from used plastics. NBC insight into how pyrolysis processes differ between feedstocks and into properties of pyrolysis oil-derived products has helped to commercialize phenolic adhesives made from pyrolysis oil.

Jim Yost Photography/PIX 12681

With the Thermochemical Users Facility, National Bioenergy Center researchers and industrial partners can gasify or pyrolyze up to one-half ton per day of biomass; analyze the composition of the product syngas or pyrolysis oil; and then test its use in a gas turbine or internal combustion generator.

The National Bioenergy Center's Bioprocessing Pilot Plant can process up to one ton per day of raw cellulosic feedstock or start with sugars or other intermediates. Either way, it permits testing of complete processes and includes fermentation in bioreactors as large as 9000 liters. This ability to operate a full process on a relatively large scale provides a key tool for proving and advancing bioprocessing technologies.

Warren Gretz, NREL/PIX 01008

Biobased Products: In addition to leading bioenergy R&D for fuels and power, the NBC also develops chemical and biological technologies for producing new biomass-based products, such as polymers, structural materials, and composites, to complement or replace current non-renewable products. The NBC is collaborating with a wide array of industry, academia, and other government laboratories to develop sustainable technologies for synthesizing chemicals and other products from biomass.

Conversion Facilities

The NBC has state-of-the-art biochemical and thermochemical process development units at DOE's NREL for evaluating integrated technologies for converting biomass into fuels, chemicals, and valuable products. Both are designated user facilities, available for industrial partners and technology developers to use under a variety of collaborative agreements.

Alternative Fuels User Facility: The Alternative Fuels User Facility (AFUF), with its one-ton-per-day-feedstock Bioprocessing Pilot Plant and supporting laboratories, is at the heart of U.S. efforts to develop cost-effective cellulosic ethanol and other biomass-to-chemicals technologies. The AFUF's 10,000-square-foot pilot plant allows testing and development of complete production processes (or critical parts of production processes), from bench to pilot scales. Fermentation trials can be performed with a variety of aerobic or anaerobic microorganisms—including genetically modified strains—in batch, fed-batch, or continuous mode, using 160-liter to 9,000-liter bioreactors. The fermentation portion of the pilot plant can also be used to further partners' R&D using sugar or other intermediate biomass components rather than cellulosic feedstocks. Whether used from start to finish for cellulosic bioprocessing or for particular steps of conversion technology, the AFUF is an ideal resource for the NBC and industry to lay groundwork for technology needed to develop biorefineries of the future.

Thermochemical User Facility: The Center's state-of-the-art Thermochemical Users Facility (TCUF) at NREL simulates novel and commercial gasification, pyrolysis, and combustion processes. The TCUF's 0.5 ton-per-day process development unit (PDU) is based on a fluidized bed reactor coupled with a thermal cracker (tubular reactor) that allows broad flexibility in process conditions and product composition. A variety of particulate removal, secondary catalytic conversion, and condensation equipment are available. Because of the PDU's modular design, it can also readily accommodate other equipment supplied by research partners. Products and intermediates can be analyzed on-line by several methods, including gas chromatography, molecular beam mass spectrometry, non-dispersive infrared spectrometry, residual gas analysis, and Fourier transform infrared spectrometry. Process mass balances are continuously computed from on-line data.

Raw synthesis gas and pyrolysis vapors can be upgraded using a fluidized bed catalytic reactor and a Xytel catalyst test unit. A variety of end uses can be evaluated, including power generation (internal combustion engine and microturbine) and fuels/chemicals production (microcatalytic reactor). Collectively, these capabilities provide a unique research and development facility that facilitates the optimization and integration of novel and evolving thermochemical biomass conversion processes.

Other Biomass Conversion Facilities: At ANL, the NBC has a mobile pilot-scale membrane separator available for demonstrating catalysis and separation technologies with industrial partners. ORNL has bioprocessing facilities, including fluidized- and fixed-bed bioreactors, as well as thermocatalytic reactors. PNNL has a wet gasification pilot plant and a multiple-catalyst test reactor. All are available for NBC research and collaborations with industry.

Analytical Capabilities

Wet Chemistry: NBC staff are well versed in all of the traditional analyses for biomass feedstocks and biomass processing. Most of the standard biomass analytical techniques published by the American Society for Testing and Materials and the Technical Association of the Pulp and Paper Industry are based on NBC-developed procedures.

Rapid Analysis: The NBC's Rapid Analysis techniques for biomass take near-infrared spectrometry coupled with multivariate analysis to a new level of sophistication. Within minutes instead of days, users can analyze a wide range of physical and chemical properties of raw and processed biomass. The Rapid Analysis techniques can be applied profitably at almost any point in any industrial biomass process. NBC staff and facilities also support the Biomass Rapid Analysis Network, a consortium of individual biomass-processing companies set up to facilitate transfer of Rapid Biomass Analysis capabilities to network members.

Molecular-Beam Mass Spectrometry: The NBC has developed sampling methods based on molecular beam mass spectrometry coupled with multivariate analysis for studying the high-temperature, reactive-product gas streams encountered in biomass thermochemical conversion processes. Comprehensive detection of all gas-phase and condensable species of interest is possible using the mass spectrometer. Also, facilities for pattern matching and tandem mass spectrometry are available to aid in deciphering complex mass spectra. This technology can be used in the field as well as in the laboratory to analyze thermochemical biomass conversion processes. NBC researchers developed a unique transportable instrument that can be directly connected to an industrial partners' process for real-time process monitoring, optimization, and ultimately control.

Catalyst and Surface Reaction Analysis: The Environmental Molecular Science Laboratory at the PNNL, a designated user facility available to the NBC and industrial collaborators, is a world-class facility for analyzing chemical and biological catalytic reactions on biomass surfaces. Such surface science characterization is a key research area for biomass processing technology. PNNL also has combinatorial catalysis instrumentation capable of very rapid screening of chemical catalysts for biomass processing over a wide range of temperatures and pressures. This instrumentation is valuable for identifying ways of producing high-value chemicals from biomass sugars. The NBC is also adding an array of surface analysis instruments at NREL to expand its capabilities for studying surface morphology and chemical changes during biomass conversion.

Jim Yost Photography/PIX 12677

Rapid biomass analysis is an invaluable tool for developing biomass conversion technologies. Instead of waiting for expensive, time-consuming wet-chemical laboratory analyses, feedstocks, intermediates, and final products can be non-destructively analyzed virtually instantaneously. National Bioenergy Center researchers developed this near-infrared spectrocopy/multivariate analysis-based technology, have already incorporated it into much of their research, and are making it available to industrial users through a partnership network.

Techno-Economic Analysis: NBC engineers set the standard for techno-economic analysis of potential biomass processes, assessing feasibility, guiding process choices, and identifying key research areas. NBC process engineers have developed process designs and sophisticated ASPEN+ models for several biological and thermochemical biomass conversion processes, including ethanol and synthesis gas production. NBC ecologists and economists are also linking feedstock production cost models with transportation and agricultural and forest demand sector models to understand biomass markets and competition for land and biomass resources. Further linkages to input/output modules allow researchers to understand the macro-economic implications of bioenergy systems.

Life-Cycle Assessment: NBC analysts are also at the forefront of life-cycle assessment, used for determining the environmental impacts of biomass conversion (or other renewable or fossil energy) technologies, using a cradle-to-grave approach that includes biomass feedstock growth, harvest, conversion, and product use. NBC researchers at NREL can also conduct life-cycle assessment of specific technologies for industrial partners.

The NBC also has access to ANL's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, a sophisticated fuel-cycle simulation. The GREET Model allows researchers to evaluate various engine and fuel combinations on a consistent fuel-cycle basis.

National Bioenergy Center expertise, capabilities, facilities, and technologies can be made available to you through cooperative research and development agreements, work-for-others agreements, licenses, and other collaborative business arrangements. Please contact us to discuss how we can help you meet your research and development needs.

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1000 Independence Avenue, SW, Washington, DC 20585
by the National Renewable Energy Laboratory, a DOE national laboratory

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DOE/GO-102003-1782 November 2003

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% postconsumer waste.