



NATIONAL  
BIOENERGY CENTER

## INTEGRATED BIOREFINERY RESEARCH FACILITY

### Partnering with Industry to Advance the Bioeconomy

For more than 30 years, the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) has been at the leading edge of research and technology advancements to develop renewable fuels and bioproducts. NREL works to develop cost-competitive alternatives to conventional transportation fuels and value-added bio-based chemicals that can be used to manufacture clothing, plastics, lubricants, and other products.

NREL is developing technologies and processes to produce a range of sustainable, energy-dense advanced biofuels and renewable chemicals and materials. As part of that effort, NREL's National Bioenergy Center has entered into more than 130 collaborations in recent years with companies ranging in size from start-ups to those that appear on Fortune magazine's Fortune 100 list.

The Integrated Biorefinery Research Facility (IBRF) showcases NREL's commitment to collaboration and to meeting the nation's biofuel and bioproduct development and deployment goals. Designed to speed the growth of the biofuel and bioproduct industries, the IBRF is a unique \$33.5-million pilot facility capable of supporting a variety of projects.

The IBRF is available to industry partners who work with NREL through cooperative research and development, technical, and analytical service agreements. With 27,000 ft<sup>2</sup> of high-bay space, the IBRF provides industry partners with the opportunity to operate, test, and develop their own biorefining technologies and equipment.

### Research Flexibility

The IBRF can handle a wide range of biomass feedstocks and pretreatment processes. Parallel pretreatment processing trains allow for the testing of conversion processes using a variety of technologies under a



wide range of conditions. The IBRF can handle high concentrations of solids (10%–40%) in the pretreatment and enzymatic hydrolysis steps, a key factor in reducing costs. Bioreactors from 10 L to 9,000 L and separation and concentration equipment are housed in the IBRF allowing for biomass conversion processes to be fully integrated.

### Access to Experts

While using the IBRF, industry partners have access to NREL's world-renowned experts, process equipment, and systems that can be used to develop and evaluate commercial processes for the production of bio-based products and fuels. In addition, partners have access to NREL's state-of-the-art molecular biology, biochemistry, and biomass compositional analysis laboratories. Advanced biofuels produced in the IBRF can be tested and analyzed in NREL's fuel testing laboratories, and data generated in the IBRF can be incorporated into techno-economic and life-cycle analysis models to estimate the feasibility and sustainability of commercial-scale production.

By leveraging the investments DOE has made in the IBRF and NREL, industry partners can develop conversion processes and technologies faster and shorten the commercialization cycle for biofuels and bioproducts.



Top Photo: The IBRF pretreatment reactors (upper) and high-solids enzymatic hydrolysis reactors (lower). *Photo by Dennis Schroeder, NREL 33952*

Bottom Photo: Four 9,000-L bioreactors available for large-scale microbial conversion processes. *Photo by Werner Slocum, NREL 41912*

## Pretreatment Capabilities

- **Continuous 1-ton/day vertical pretreatment reactor system with multiple reactors**
  - Residence times: 5–100 minutes, temperature range: 120°C–210°C, Hastelloy C-2000 construction compatible with a range of pretreatment chemistries
- **Continuous 1-ton/day horizontal pretreatment reactor system with the capability for multiple configurations**
  - Residence times: 3–120 minutes, temperature range: 150°C–210°C, Hastelloy C-2000 and 316 stainless steel construction compatible with a range of pretreatment chemistries
- **Continuous 200-kg/day (dry basis) horizontal-screw pretreatment reactor system**
  - Residence times: 3–30 minutes, temperature range: 130°C–200°C, Hastelloy C-2000 construction
- **High-solids batch paddle reactor (up to 1,500 L) and dewatering screw press**
- **Low-severity atmospheric-pressure mechanical milling systems (disk refining and compression milling)**
- **4-L batch steam gun pretreatment reactor system**
- **1-L stirred high-solids batch pretreatment reactor system**

## Enzymatic Hydrolysis and Fermentation

- **High-solids 4,000-L horizontal paddle-type reactors**
  - Operate at total solids loading >20% (w/w)
  - Operate in batch mode to achieve semi-continuous processing at a temperature range of 40°C–75°C
- **Systems for injecting neutralizing chemicals and enzymes**
- **Bioreactors (continuous or batch/aerobic or anaerobic)**
  - Multiple stirred bioreactor systems from 10 L to 100 L
  - Two 160-L stirred vessels; two 1,500-L stirred vessels; four 9,000-L stirred vessels
  - Numerous supporting laboratory-scale bioreactor systems
  - Feed and support vessels (stirred) ranging in size from 100-L to 9,000-L

## Downstream Processing Equipment

- **10-m-tall by 0.5-m-diameter sieve tray distillation column**
- **Continuous forced recirculation evaporator for concentrating or evaporative operations at atmospheric pressure or vacuum conditions**
- **High-speed disk-stack centrifuge (10,000 G) for cell recovery and fine particle removal**
- **Continuous decanting centrifuge (3,000 G) with 1,200-L/hour capacity**
- **Semi-automatic perforated basket centrifuge (900 G) with automatic feed, discharge, and washing capability**
- **Semi-continuous rotary drum vacuum filter**
- **Continuous sterilizer**
- **Recirculating crossflow membrane filtration system with diafiltration capability for solid-liquid separation of highly deconstructed biomass slurries or cell removal from fermentation broths**

## Other Capabilities

- **Compositional analysis**
  - Wet chemistry and near-infrared spectroscopy
  - High-performance liquid chromatography and spectrometers (infrared, visible, and ultraviolet)
- **Pilot-plant monitoring**
  - Real-time data acquisition and dedicated mass spectrometer for online monitoring of fermentation exhaust gas composition
- **Molecular biology laboratories**
  - Development of enzymes and biocatalysts
    - Strain engineering
    - Proteomics
    - Transcriptomics
    - Metabolomics

## Find Out More

For additional information about the IBRF, including inquiries about equipment, capabilities, or partnership opportunities, contact:

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