NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Biochemical Conversion Pilot Plant

A pilot-scale conversion plant for researchers, industry partners, and stakeholders to test a variety of biochemical conversion processes and technologies.

NREL's biochemical conversion pilot plant is located in the Integrated Biorefinery Research Facility (IBRF).
Photo by Dennis Schroeder, NREL/PIX 20248

In the biochemical conversion pilot plant, NREL's engineers and scientists focus on all aspects of the efficiency and cost reduction of biochemical conversion processes. Our capabilities accommodate research from bench-scale to pilot-scale (up to one ton per day).

Pilot Plant Resources

Pretreatment

- Bench- and pilot-scale biomass chemical impregnation and dewatering systems (screw presses)
- 1-L high-solids stirred batch reactor
- 4-L steam-injected batch reactor
- 130-L steam-jacketed and steam-injected batch paddle-type mixed reactor limited to <160°C
- Continuous horizontal screw-type reactor, 100-200 kg per day (dry basis) capacity (140°-210°C and 5-30 min residence times)
- Continuous horizontal screw-type reactor, 0.5-1.0 ton biomass per day (dry basis) capacity (140°-210°C and 3-120 min residence times)
- Continuous vertical reactor, 0.7-1.0 ton biomass per day (dry basis) capacity (140°-200°C and 1-60 min residence times)
- Continuous vertical reactor, 0.5-1.0 ton biomass per day (dry basis) capacity (140°-210°C and 10-40 min residence times), with an in-line secondary reactor for optional treatment at lower temperatures
- All reactor systems have multiple options for pretreatment catalysts.

Enzymatic hydrolysis

- High-solids bench-scale tumbling reactors (up to 10 L)
- 1,900-L hot-water jacketed paddle reactor for high solids slurries
- Four 4,000-L hot-water jacketed paddle reactors for semi-continuous processing at total solids loadings greater than 20% (w/w).

Fermentation

- Multiple stand-alone fermentation systems from 15-L to 100-L scale
- Pilot plant fermentation train consisting of two 160-L seed production vessels, two 1,500-L seed production vessels, and four main 9,000-L fermentation vessels
- All vessels can be operated in either batch, fed-batch, or continuous mode of operation
- Continuous high-temperature, short residence time sterilizer.

Product separation and recovery

- Solid-liquid separation systems, solid-bowl and perforated-bowl centrifuges
- Semi-continuous pressure belt filter
- Forced-recirculation evaporator
- 19-sieve tray distillation column.

Process-related capabilities

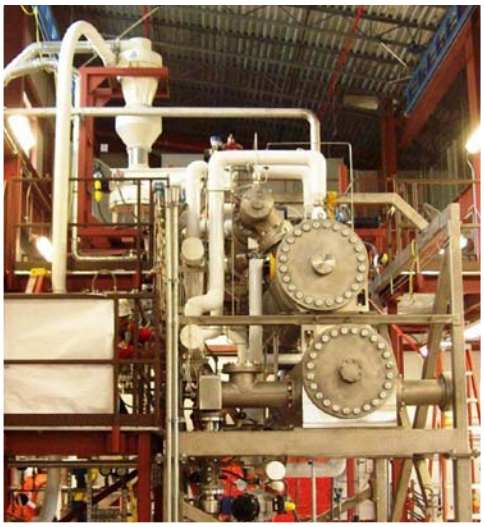
- Compositional analysis
- Process engineering and economic analysis
- Molecular biology
- Microscopy analysis
- Rheology and particle size characterization
- High throughput processing and analysis
- Computational modeling.

**NREL is a national laboratory of the U.S. Department of Energy,
Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.**

Capabilities and Expertise

- **Feedstock and pretreatment research flexibility –** an unprecedented level of versatility for handling a wide range of biomass feedstocks and pretreatment processes
- **Equipment integration –** ample space for customer equipment for end-to-end process integration, testing, and evaluation
- **Broad range of biomass, enzymes, and microorganisms handling –** experts can readily integrate technologies to pilot scale testing and process validation
- **Access to experts –** world-renowned staff of engineers and scientists to industrialize new discoveries and move technologies to markets faster
- **Data quality –** automated process control and data acquisition systems, and world-class chemical analysis capabilities, for high-quality data
- **Process technology breakthroughs –** proven experience commercializing technology developed with industrial partners
- **Research publications –** increased visibility with academia, industry, and governments
- **Patent potential –** extensive experience implementing patents developed with partners.

NREL is a pioneer in developing and scaling up bacterial strains for efficient ethanol production. Using genetic and metabolic engineering techniques, NREL modified the bacterium *Zymomonas mobilis* (Zymo), an alternative to yeast, to ferment xylose to ethanol. This strain resulted in several patents and an R&D 100 Award. NREL also pioneered a technique to make the Zymo strain stable, by inserting key genes into the genome, and has made strains that convert both xylose and arabinose to ethanol. NREL's Zymo work has included successful collaborations with the National Corn Growers Association, the Corn Refiners Association, and DuPont.



NREL's multi-tube horizontal reactor system for biomass pretreatment. *Photo by Dan Schell, NREL/PIX 18296*

Associated publications

Chen, X.; Shekiro, J.; Elander, R.; Tucker, M. (2012). "Improved Xylan Hydrolysis of Corn Stover by Deacetylation with High Solids Dilute Acid Pretreatment." *Industrial and Engineering Chemistry Research* (51); pp. 70-76.

Humbird, D.; Davis, R.; Tao, L.; Kinchin, C.; Hsu, D.; Aden, A.; Schoen, P.; Lukas, J.; Olthof, B.; Worley, M.; Sexton, D.; Dudgeon, D. (2011). *Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol: Dilute-Acid Pretreatment and Enzymatic Hydrolysis of Corn Stover.* NREL/TP-5100-47764. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy11osti/47764.pdf.

Weiss, N.; Farmer, J.; Schell, D.J. (2010). "Impact of Corn Stover Composition on Hemicellulose Conversion during Dilute Acid Pretreatment and Enzymatic Cellulose Digestibility of the Pretreated Solids." *Bioresource Technology* (101); pp. 674-678.

Schell, D.J.; Farmer, J.; Newman, M.; McMillan, J.D. (2003). "Dilute-Sulfuric Acid Pretreatment of Corn Stover in Pilot-Scale Reactor: Investigation of Yields, Kinetics, and Enzymatic Digestibilities of Solids." *Applied Biochemistry and Biotechnology* (105-108); pp. 69-86.

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