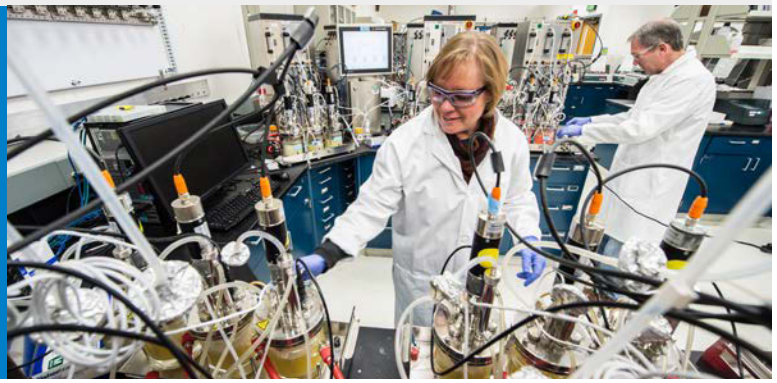
NREL | NATIONAL BIOENERGY CENTER

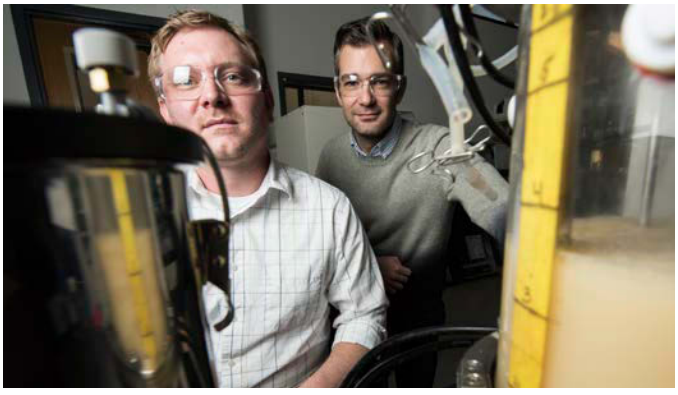
NREL'S CAPABILITIES IN **ORGANISM DEVELOPMENT AND FERMENTATION SCIENCES RESEARCH AND DEVELOPMENT (R&D)**



NREL is developing robust microbial strains and scalable fermentation technologies for converting biomass sugars to fuels and biochemicals, and one-carbon (C1) gaseous substrates (e.g., CO_2, CO, CH_4) to high-value products.

Core Capabilities

- Fermentation optimization of aerobic, micro-aerophilic, and anaerobic cultivation processes of gas and traditional liquid fermentation R&D
- Gas mass transfer R&D and CFD modeling for improved reactor design and gas mixing
- Metabolic engineering in CRISPR editing tools to improve titer, rates, and yields
- Probing and optimizing carbon, redox, and energy flux using transcriptomics and fluxomic techniques
- Consolidated bioprocessing (CBP) using cellulose and hemicellulose directly to minimize pretreatment



Top Photo: One of NREL's bench-scale fermentation laboratories with 36 500-mL Sartorius stirred tank bioreactors. *Photo by Dennis Schroeder, NREL 35821*

Bottom Photo: NREL researchers discover how Methylomicrobium alcaliphilum 20ZR, a methane-eating organism known as a methanotroph, operates. It was one of the first research efforts of its kind. *Photo by Dennis Schroeder, NREL 49737*

Standard Bench-Scale Fermentation

NREL's bench-scale fermentation laboratories house a variety of fermentors sized from microbioreactors to 10-L benchtop units. All units have dissolved oxygen monitoring and control, pH and temperature control, and data acquisition. Most systems have off-gas analysis.

- Thirty-six 500-mL Sartorius BIOSTAT® Q-plus bioreactors with mass spectrometer for off-gas analysis
- Three Eppendorf 300 series fermentors with 5-L or 10-L vessels
- Six Applikon® In-Control series fermentors with 3L vessels with remote access/control and off-gas measurement using gas chromatography
- Seven New Brunswick 3000 series fermentors with 1-L to 10-L vessels with mass spectrometer for off-gas analysis
- BioLector Pro microbioreactor

C1/Gas Fermentation

NREL has developed state-of-the-art gas fermentation capabilities from bench to pilot-scale demonstrating production of renewable fuels and chemicals from tailored ratios of hydrogen and C1 gaseous substrates (e.g., CH_4, CO, CO_2, and H_2). All fermentor systems are fully instrumented with safety interlocks and off-gas analysis.

- Coming in 2020, a mobile lab-scale 10-L to 30-L pressurized (18 bar) bioreactor with integrated 10-kW to 15-kW PEM electrolyzer
- Hooded Applikon In-Control Series 200-mL for CO and H_2 fermentations with off-gas GC analysis
- Two hooded Electrolab 2-L fermentors for CO, CO_2, and H_2 fermentations with off-gas GC analysis
- CH_4 fermentation capability in 50-mL small-format bubble reactors and three 500-mL Sartorius bioreactors with mass spectrometer for off-gas analysis

Pilot-Scale Gas Fermentation

NREL operates a pilot-scale 700-L gas bioreactor with capabilities to convert renewable hydrogen and CO_2 to fuels and chemicals at pressures up to 18 bar. This state-of-the-art system has nutrient dosing pumps, heat rejection, and cell retention with in-house production of renewable hydrogen via 250-kW PEM electrolyzer. The system is fully instrumented with Coriolis mass flow meters, pressure/temperature/level sensing, GC analysis, pH monitoring paired with data acquisition, and control and data visualization capabilities.

The Energy Systems Integration Facility's 700-L pressurized gas bioreactor designed for hydrogen and carbon dioxide gas feeds.

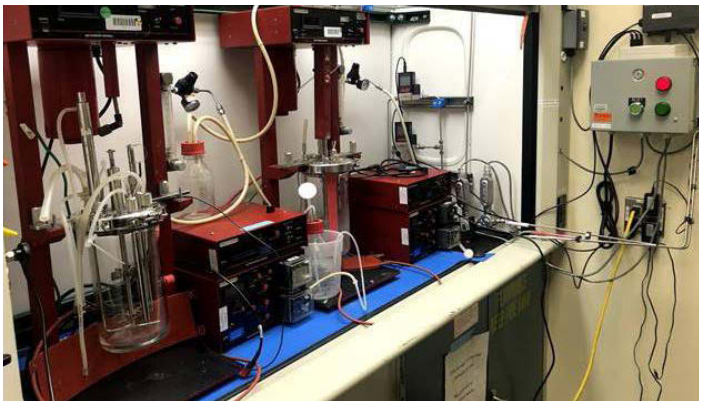
Photo by Dennis Schroeder, NREL 58759

KEY RESULTS

Recent efforts have demonstrated high product titers from biomass sugars, utilization of carbon dioxide to products and fuels, and CH_4/CO_2 conversion to chemicals.

Recent Accomplishments from Fermentation R&D

- Demonstrated 2,3-butanediol titer of 110 g/L from biomass sugars and scaled fermentation process to 100-L pilot fermentor.
- Commissioned the pilot-scale 700-L pressurized gas bioreactor to produce renewable CH_4 from CO_2 and renewable H_2.
- Established CH_4/CO_2 co-utilization capacity in microbial biocatalysts, which enable conversion of diverse gaseous waste streams including anaerobic digestion biogas and landfill gases.
- Developed CRISPR tools to edit microbial genomes and generated strains capable of co-fermenting cellulose and hemicellulose via CBP, fix CO_2 with high carbon-conversion efficiency and developed the first CRISPR editing system in methanotrophic bacteria.



Hooded Electrolab 2-L fermentors for CO, CO_2, and H_2 fermentations.
Photo by Lauren Magnusson, NREL

Find Out More

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Highlighted Publications

Brunecky, R., Subramanian, V., Yarbrough, J.M., Donohoe, B.S., Vinzant, T.B., Vanderwall, T.A., Knott, B.C., et al. "Synthetic Fungal Multifunctional Cellulases for Enhanced Biomass Conversion." *Green Chemistry*. December 18, 2019.

Gionet, A. "NREL 'Bug' Creates Renewable Natural Gas." *CBS 4 Denver*. March 3, 2019.

Henard, C.A., Akberdin, I., Kalyuzhnaya, M.G., and Guarnieri, M.T. "Muconic Acid Production from Methane Using Rationally-Engineered Methanotrophic Biocatalysts." *Green Chemistry* 21(24):6731–6737. 2019.

Lacey, S. "Are Ancient Bugs the Key to Storing Wind and Solar?" *Green Tech Media*. October 15, 2019.

Marcano-Velazquez, J.G., Lo J., Nag, A., Maness, PC, and Chou, KJ. "Developing Riboswitch-Mediated Gene Regulatory Controls in Thermophilic Bacteria." *ACS Synthetic Biology*. 8(4):633–640. April 19, 2019.

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