DOE Thermochemical Users Facility
A Proving Ground for Biomass Technology

Biomass — Fuels, Chemicals, Materials, and Power

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

Making Gaseous and Liquid Fuels and Valuable Chemicals from Biomass

Heating solid hydrocarbons and carbohydrates (fossil fuels or biomass) with limited or no oxygen, can gasify, pyrolyze, or steam-reform them to gaseous syngas (a mixture of carbon monoxide and hydrogen), liquid pyrolysis oil, or other intermediate products, depending on the temperature, amount of oxygen, and use or not of steam. Both syngas and pyrolysis oil are inherently cleaner burning and more flexible fuels than the original solid biomass, but they can also be converted into more valuable fuels and chemicals. U.S. Department of Energy scientists are at the forefront of biomass gasification and pyrolysis research. In Golden, Colorado, they have a world-class facility for developing and proving their own gasification and pyrolysis technologies and those of industrial partners.

Is your company developing or considering products or technology based on gasification or pyrolysis of biomass? Could you benefit from the opportunity to test that technology in a world-class facility—staffed by leading experts in the field—without having to construct your own pilot plant facility?

The National Bioenergy Center at the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) provides a state-of-the-art Thermochemical Users Facility (TCUF) for converting renewable, biomass feedstocks into a variety of products, including electricity, high-value chemicals, and transportation fuels. This biomass refinery consists of integrated unit operations that can be configured to accommodate the testing and development of various processes. Reactors, filters, catalysts, and other unit operations can be inserted into the process development unit for evaluation by mutiple users. Combined with the expertise of NREL researchers, the TCUF offers clients an unsurpassed opportunity to test their process ideas in a timely and cost-effective manner, and to quickly and safely obtain extensive performance data on their processes or equipment.

Key Components

The key components in the TCUF are the Thermochemical Process Development Unit (TCPDU), the Catalyst Testing Unit, and the Generator Test Cell. The TCPDU can be integrated with downstream Catalytic Synthesis Units to produce fuels and chemicals, or with the Generator Test Cell to produce electricity.

Jim Yost Photography/PIX 12684

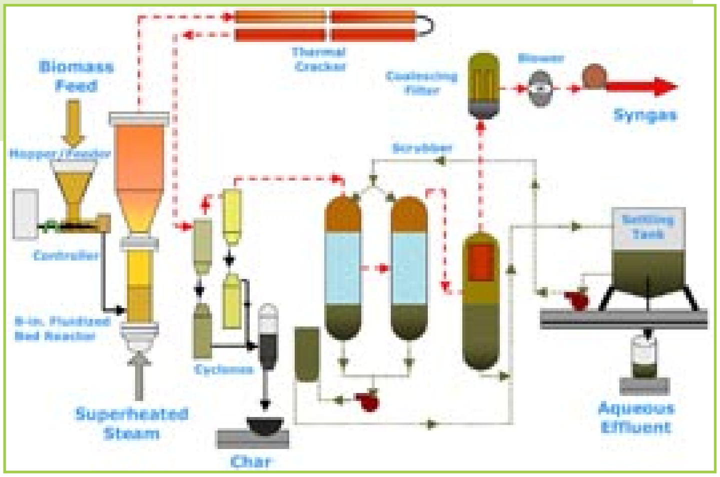
Flexibility, modularity, moderate cost, abundant data, multiple integrated-unit-operation evaluation, bench-scale to commercialization linkage—the DOE Thermochemical Users Facility offers industrial partners a multitude of benefits, without the time and expense of building their own facility.

Thermochemical Process Development Unit (TCPDU)

The heart of the TCUF is a 0.5 ton-per-day-feedstock [10-25 kg (22-55 lb) –per-hour] Thermochemical Process Development Unit (TCPDU). Depending on the research needs, the TCPDU can be operated in either gasification or pyrolysis mode. Its main purpose is to provide authentic biomass–derived product streams that are precisely controlled, measured, and characterized. Specific research objectives determine how the product stream may be used or integrated with other TCUF operations such as gas cleaning and conditioning, fuels synthesis, or power generation. The main unit operations in the TCPDU include:

- Loss-in-weight, rotary valve feeding system
- 8-inch diameter fluidized bed reactor
- 1.5-inch diameter by 100 feet tubular thermal (steam) cracking reactor
- Two cyclones in series
- Hot baghouse filter
- Full-stream catalytic tar cracker
- Wet scrubber system.

The TCPDU operates at atmospheric pressure and can handle reaction temperatures as high as 875°C. Additional unit operations allow for evaluation of alternate process configurations. A variety of particulate removal, secondary catalytic conversion, and condensation equipment are available. Because of the TCPDU's modular design, it can also accommodate other types of equipment supplied by research partners.



Two-Inch Fluidized Bed Reactor and Fuels Synthesis Reactor

Another key component of the TCUF is its two-inch fluidized bed reactor (2FBR) which is used to catalytically reform pyrolysis vapors to hydrogen, and catalytically reform gasifier tar in raw syngas. In addition to being a stand-alone operation for conducting catalyst studies, the 2FBR is also frequently used to catalytically condition slipstreams from the TCPDU. This system is large enough to guide scale-up of future processes yet small and versatile enough to yield this information in a reasonable time frame.

Jim Yost Photography/PIX 12678

Gas cleanup with systems such as these scrubbers is a key element of biomass gasification. Excessive tar builds up on and interferes with generating equipment operation, as well as causing hazardous air emissions. NREL researchers have developed substantial expertise in limiting tar production and in removing tar from the biomass syngas.

A separate fuels synthesis (Autoclave Engineering) reactor converts syngas to liquid fuels such as methanol, mixed alcohols, and diesel fuel. The ability to catalytically synthesize a wide-range of chemicals from syngas is an exciting aspect of thermochemical processing of biomass. Commercially proven fuels synthesis technologies can be tested with conditioned biomass-derived syngas to evaluate how best to integrate these into a biorefinery.

Generator Test Cell

The TCUF's generator test cell (GTC) allows researchers to investigate and develop strategies for integrating biomass gasifiers with power generation equipment. The GTC uses wet-scrubbed syngas from the TCPDU to produce power in a variety of configurations.

The GTC can test syngas power generation with internal combustion engines, gas turbines, or fuel cells. It includes a 2.5-liter, 4-cylinder, spark-ignited engine directly coupled to a 17-kW generator, a 30-kW Capstone micro-turbine, and a 5-kW solid-oxide fuel cell. In addition to testing syngas produced in the TCPDU, these electrical generators can be operated on natural gas or with synthetic syngas made by mixing bottled gases in an automated gas-mixing manifold. This allows for direct comparisons of emissions and operating characteristics over a range of operating conditions for various fuel compositions.

Real-Time Sampling and Chemical Analysis

The TCUF facility and laboratories are unique in that they have the capability to analyze products on-line over a wide spectrum of chemical compositions. A collection of dedicated analytical instruments has been assembled and connected to the process with special sampling methods. The analytical equipment used throughout the TCUF include:

- A molecular-beam mass spectrometer
- Three gas chromatographs
- Eight non-dispersive infrared sensors
- A thermal conductivity detector
- A paramagnetic oxygen sensor
- A residual gas analyzer
- A comprehensive exhaust emissions bench.

Together these instruments provide for a range of spatial and temporal resolution for the commonly occurring species found in biomass gasification and pyrolysis products. The species that can be detected include: H_2, CO, CO_2, CH_4, $C_{2's}$ - C_{25+}, H_2S, HCl, H_2O, O_2, N_2, NH_3, NO_x, SO_x, and CH_2O. In many cases, duplicate species detection is available to permit cross-calibrations and checks. NREL has also developed a transportable molecular-beam mass spectrometer (TMBMS). This allows sophisticated analytical capability to be taken on the road to provide on-line sampling at customer's sites, as well as in the TCUF.

Process Control

The TCPDU has extensive instrumentation for supervisory control and data acquisition. By continuously monitoring process streams at key locations, operators can assure that mass closure is obtained before and during analytical measurements. This state-of-the-art process control system is interconnected with the analytical instruments' control computers to create a single integrated database. Chemometric computer analysis of all collected data can be used for rapid process optimization.

Other Components and Capabilities

- Bench-scale unit operation for testing 500-g quantities of fluid-cracking-like catalyst
- Catalytic steam-reforming unit operation
- High-pressure batch and continuous-flow reactors
- Micro activity test unit
- Solvent vapor cracking unit
- Catalyst synthesis
- Training in gasifier fundamentals and operations.

Expertise/People

Since the TCUF was commissioned in 1996, DOE and its partners have been demonstrating and evaluating the thermochemical conversion of renewable energy feedstocks. The NREL engineers and scientists who staff the TCUF have developed a diverse range of skills associated with converting feedstocks into valuable products, as well as the analytical techniques and instrumentation to characterize the process. This staff is available to plan and conduct experiments and interpret data using the latest statistical techniques.

Jim Yost Photography/PIX 12676

The Thermochemical Users Facility is equipped with sophisticated process monitoring and operation control systems. This control room simultaneously monitors all key operating parameters.

The Thermochemical Users Facility's generator test cell allows analysis and direct comparison of emissions and operating characteristics for electrical generation by a gas turbine (foreground), an internal combustion generator (background), or a fuel cell, with biomass gas generated by different processes or from different feedstocks.

Jim Yost Photography/PIX 12666

Partnerships

The TCUF can be configured to accommodate the testing and development of a client's equipment or process to generate extensive performance data with a modest investment of time and money. The TCUF can be an important step in the commercialization process and can help to reduce the time from the lab to the marketplace for novel biomass technologies. Government agencies, universities, and a variety of industries have taken advantage of the flexibility offered by of the TCUF to evaluate and validate their process options.

In 2002, a biological reactor was connected to a gasification slip stream to test the resiliency of the medium to form hydrogen gas. The slip stream from the TCPDU contains all of the chemical species of gasification that may harm biological processes. By using a real gas stream, a realistic result was obtained from the study.

A partnership between NREL researchers and a team of industrial and academic organizations from Georgia used the TCUF to support and advance a pre-commercial demonstration plant to produce hydrogen from peanut shells. The pilot-scale fluidized bed catalytic steam reformer built for this project was installed in the TCUF to allow characterization and troubleshooting of the reactor. After 50 hours of testing and optimization, the reactor was removed from the facility and shipped to the industrial partner in Georgia. The reactor was installed at their facility and operated without the need for an extended shake down period.

NBC researchers have also hit the road to evaluate unit operations for several 10-200 ton-per-day integrated gasification combined-cycle gasifiers before full-scale testing—Battelle in 1994 and again in 1999-2000, IGT in 1994-1995, and FERCO in 1998-2002.

Working With Us

The Thermochemical users facility was designed to assist industry and other researchers developing biomass conversion and utilization technologies. The facility is available for major trials of an entire process or new feedstock, for research and development of individual biomass conversion steps, or for cooperative basic research of your or NREL's biomass conversion technologies. The DOE Thermochemical Users Facility and other 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. The National Bioenergy Center welcomes inquiries from companies and research institutions interested in using the TCUF process and analytical equipment to develop and commercialize technology for making valuable chemicals, fuels, and power from biomass.

Please contact us about the research and development work you want to do:

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