U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BIOENERGY TECHNOLOGIES OFFICE

A wide variety of non-food biomass grown across the country can be converted into advanced hydrocarbon fuels using thermochemical processes. *Photos (clockwise from upper left): iStock/3786400, Scott Butner/PNNL, iStock/6090867, Calvin Feik/NREL/16029*

Thermochemical Conversion:

Using Heat and Catalysis to Make Biofuels and Bioproducts

The Bioenergy Technologies Office works with industry and other partners to develop economical pathways that use heat, pressure, and catalysis to convert domestic, non-food biomass into gasoline, diesel, jet fuel, and other products.

Advanced biofuels are part of America's "all-of-the-above" energy strategy to develop domestic energy resources and win the global race for clean energy technology. Developing a sustainable, commercial-scale U.S. bioindustry will stimulate the economy, create new jobs, and substantially decrease net greenhouse gas emissions on a life-cycle basis.[1]

The Bioenergy Technologies Office (BETO) supports research and development (R&D) of technologies to efficiently convert algae and diverse types of cellulosic biomass (fibrous, inedible portion of plants) into renewable fuels that are compatible with today's vehicles and infrastructure. Thermochemical conversion processes apply heat, pressure, and catalysts to convert a broad range of biomass into renewable gasoline, diesel, jet fuels, chemicals, and heat and power.

Working with industry, academia, and the national laboratories, BETO has identified critical R&D barriers for specific conversion pathways. Research is needed to lower the cost, increase the efficiency, and reduce the environmental impacts of thermochemical conversion. R&D efforts are addressing these technical challenges with the goal of achieving a cost-competitive fuel price of $3 per gallon (gasoline equivalent) by 2017.

Exploring Promising Technology Pathways

BETO uses techno-economic modeling and engages key stakeholders to identify pathways that offer the greatest promise to make hydrocarbon biofuels cost competitive in the market.

Please visit BETO's Technology Pathways Web page to access the pathways characterized to date:

bioenergy.energy.gov/technology_pathways.html

1 Impacts on emissions depend upon the type of biomass used, cultivation practices, and processing.

Thermochemical Conversion

The elevated temperatures of thermochemical conversion (300°C to 1,000°C) expand the range of biomass feedstocks that can be used by the bioindustry. The ability to use a broad range of feedstocks (see back page) helps to ensure an adequate biomass supply across seasons and spreads the economic and energy security benefits across regions.

Despite these advantages to using diverse feedstocks, researchers recognize that conversion technologies and supporting processes are sensitive to variations in feedstock characteristics (moisture content, contaminants, etc.). BETO works with industry and other partners to explore ways to pretreat and blend various types of biomass into uniform formats with consistent properties. The aim is to create commodities with predictable properties that meet established criteria for efficient conversion.

Thermochemical conversion involves deconstructing biomass and upgrading the resulting intermediates into a range of fuels and other products. Research in thermochemical conversion focuses on the production of either gaseous intermediates or liquid bio-oil intermediates and their subsequent upgrading into fuels and other products.

Gaseous Intermediate Technology

Gaseous intermediates are produced by heating the biomass with less oxygen than is required for complete combustion. This approach may involve subjecting the biomass to high temperatures to produce a mixture of gases (gasification). These gases can then be converted to fuels and chemicals using catalysts or other biological processes.

BETO is exploring the pathway for upgrading one of these gaseous mixtures, known as synthesis gas (or syngas), to methanol. This pathway leverages ongoing work in gasification and syngas cleanup and offers opportunities to both improve catalyst performance (enabling higher yields) and intensify processing steps (enabling their use in smaller facilities).

R&D Challenges for Gaseous Intermediates

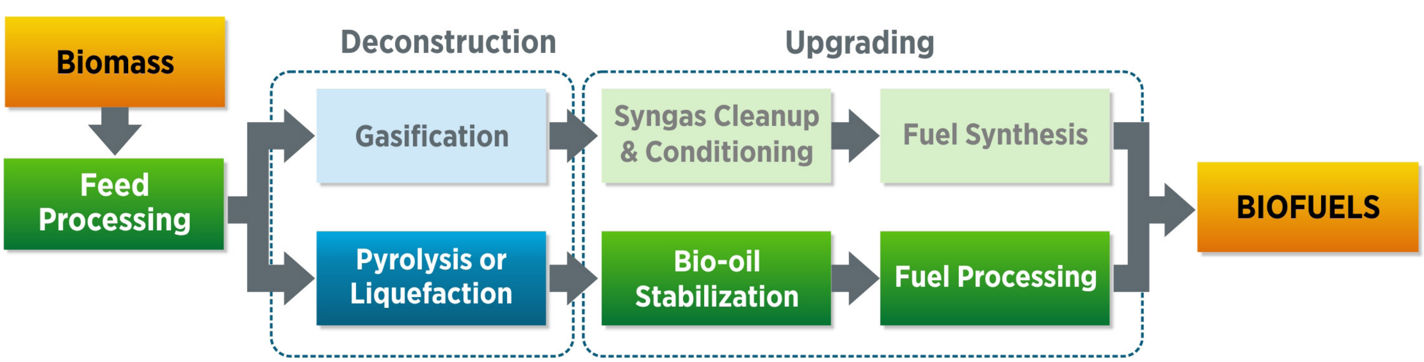
- Demonstrate reliable reactor operation
- Refine efficient gas-cleaning technologies
- Develop improved catalysts for liquid fuel production.

Bio-Oil Intermediate Technology

Biomass can be heated in the absence of oxygen to ultimately produce a liquid intermediate or bio-oil. The biomass first undergoes either a pyrolysis or liquefaction process to produce a vapor mixture, liquids, and solids. Condensing the vapor mixture yields a liquid with bio-oil and aqueous layers (as oil and water do not mix). The bio-oil can be put through hydroprocessing, separation, and fractionation steps to upgrade it into a finished fuel. Alternatively, the bio-oil may be upgraded to an intermediate product for further processing in a traditional petroleum refinery. BETO research on bio-oil intermediates currently focuses on five pathways (three pyrolysis and two liquefaction processes):

Pacific Northwest National Laboratory has developed a multi-stage hydrotreating process that can stabilize the biocrude or produce a finished hydrocarbon blend stock tailored for end use or for input to a refinery. *Photo: PNNL*

- Fast pyrolysis
- Catalytic fast pyrolysis (*ex-situ* and *in-situ*)
- Hydropyrolysis
- Hydrothermal liquefaction
- Solvent liquefaction.



R&D projects are improving thermochemical conversion routes for cellulosic and algal biomass.

R&D Challenges for Bio-Oil Intermediates

- Develop better catalysts or processes for removing oxygen and other impurities
- Improve processes for stabilizing bio-oils
- Improve catalysts for upgrading bio-oils into finished fuels.

Pathway to Diverse Biofuels and Benefits

Thermochemical processing provides an opportunity to produce advanced biofuels that deliver diverse benefits to the nation. These benefits vary by process and end product, providing flexibility in meeting market needs. Benefits include:

- **Climate Change:** On a life-cycle basis, advanced biofuels produced via thermochemical conversion could reduce greenhouse gases by 50% or more, relative to conventional gasoline.
- **Infrastructure Compatibility:** Although bio-oils can be corrosive prior to upgrading, the resulting advanced biofuels are generally compatible with the existing fuel delivery infrastructure (pipelines, tanks, pumps, blending facilities, vehicles, etc.).
- **Energy Security:** Domestic biofuels diversify the energy portfolio and decrease U.S. dependence on foreign sources of energy. Biorefineries may potentially serve as regionally independent energy facilities, improving energy security and resilience.

Integration in Traditional Refineries

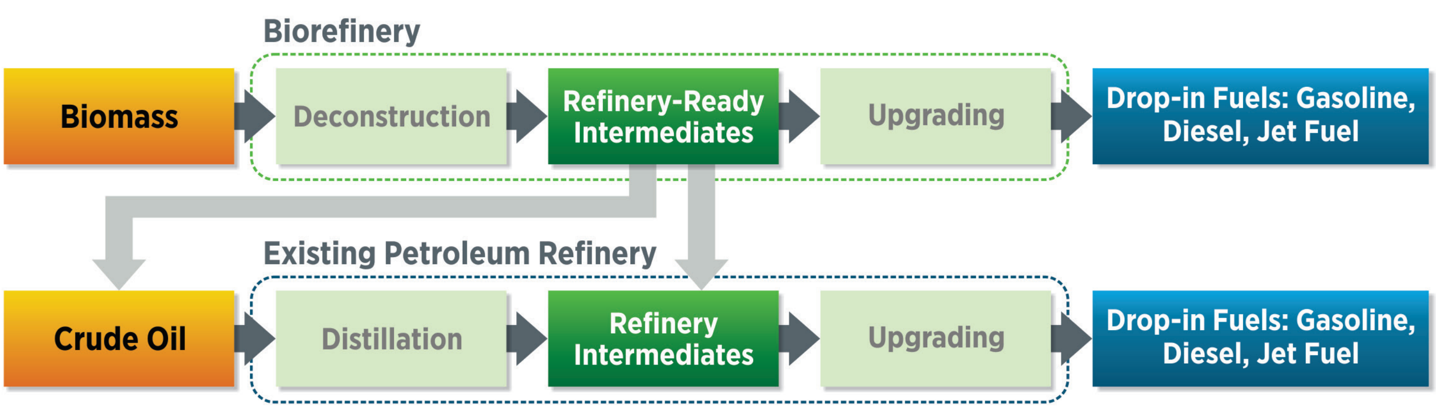
Successfully integrating biomass product streams for further processing in traditional petroleum refineries would provide refineries with a secure, domestic feedstock. Researchers are investigating compatibility criteria for crude bio-oils, biofuel intermediates, and finished hydrocarbon biofuels at various insertion points. The goal is to produce biomass-based feeds that are identical (at the molecular level) to products now found in the traditional petroleum refining product chain.

For successful integration, the biomass feed streams must be able to meet rigorous criteria. More specifically, they will need to be low in oxygen, blend well with petroleum, and be free of contaminants that could poison the refinery catalysts or degrade the product.

One challenge to the successful use of bioproducts in traditional refineries is the need to track Renewable Identification Numbers (RINs). These are the serial numbers assigned to batches of biofuel, as required by the Environmental Protection Agency. Companies that refine, import, or blend fossil fuels are periodically required to submit a number of RINs as evidence that they are doing their part in meeting national biofuels production targets. A system is needed for reliability tracking RINs when intermediate products are transferred between biorefineries and traditional refineries.

BETO research is helping to define feedstock criteria and blending formulas that will enable reliable thermochemical processing.
Photo: Art Wiselogel/NREL/04195

BETO is working to better understand the physical properties, reactivities, and compatibilities of biofuel intermediates for finishing in traditional petroleum refineries.
Photo: David Parsons/NREL/05049



Researchers are defining criteria for the insertion of biorefinery intermediates into traditional refineries.

Blending of Biomass into Uniform Feedstocks

Blending a broad spectrum of feedstocks into a consistent format that meets rigorous specifications is expected to increase the available feedstock supply, reduce feedstock costs, and facilitate efficient thermochemical conversion. For more information on biomass pretreatment and blending into commodity feedstocks for processing into biofuels, please see our brochure on "Feedstock Supply and Logistics."

Short-rotation woody crops:

These biomass crops consist of fast-growing tree species, which are often harvested within 3 to 10 years of planting.

Herbaceous crops:

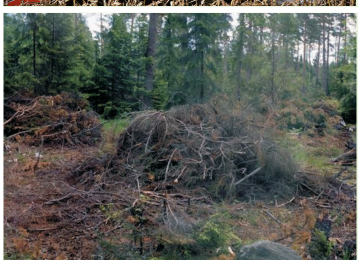
These crops typically include perennial grasses (such as switchgrass, which is native to many regions across North America).

Agricultural residues:

Waste products from agricultural activities (e.g., plant parts left in the field after harvest) and secondary residues, such as manure and food processing wastes, can be useful feedstocks.

Municipal urban residues:

Clean waste from residential, commercial, and industrial activities are included (e.g., grass clippings, unusable pallets, and municipal sorted waste).



Forestry residues:

This category includes logging residues from conventional harvest operations, forest management, and land clearing; secondary residues include mill wastes.

Oils:

This category includes algae, bio-oils (for conversion to biodiesel or for hydrotreating into green diesel), vegetable oil (e.g., from soybeans), used fryer oil, and tallow (animal fats).

Photos: (left column-top to bottom) USDA/d1253-1, INL, NREL/04190
(right column-top to bottom) USDA/k11202-1, NREL/00081, Vorticom

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