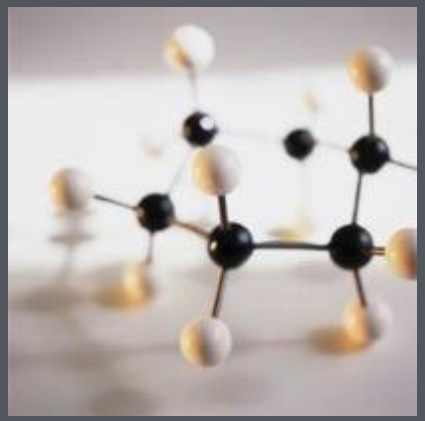
Conversion Technologies for Advanced Biofuels – Bio-Oil Production

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



Report-Out Webinar

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RTI International

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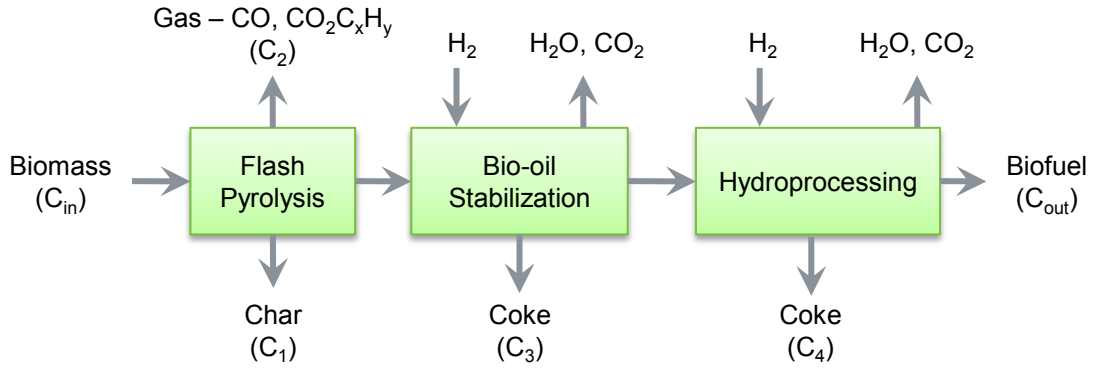
2007 – present	RTI International
1993 – 2007	National Renewable Energy Laboratory
1991-1993	U.S. Army Research Laboratory

- Ph.D., Biochemistry, University of Texas Health Science Center at San Antonio, 2000
- B.S., Biochemistry, *cum laude*, Washington State University, 1995

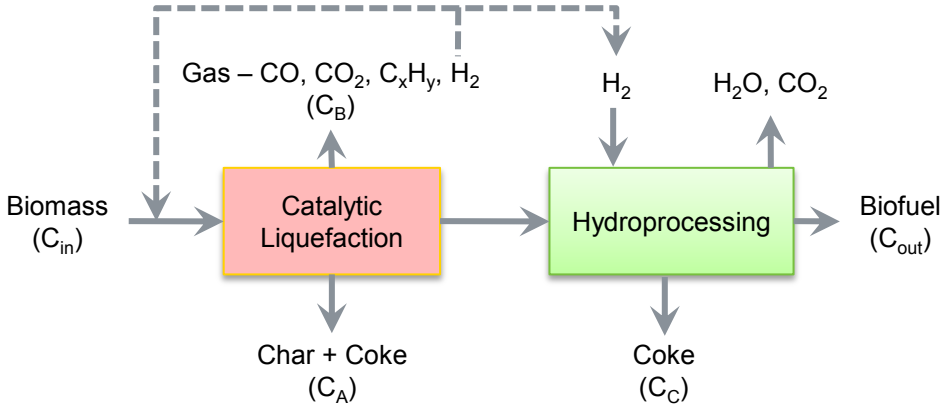
- Over 18 years of project management and research experience in biomass thermochemical conversion R&D involving biomass combustion, gasification, and pyrolysis.
- Manage projects related to synthesis gas conversion, synthesis gas cleanup and conditioning, and catalytic biomass pyrolysis.
- Focus on expanding integrated biorefinery technology development activities for biofuels production.

State-of-Technology

Current State-of-the-Art



Next Generation Technology



Bio-oil Production Technology Options

- **Fast Pyrolysis**
  (0.1 MPa and ~500° C)
- **Bio-oil Stabilization**
  (10 MPa, 150-250° C)
- **Hydroprocessing**
  (20 MPa, 300-350° C)

- **Catalytic Fast Pyrolysis**
  (0.1 MPa and ~500° C)
- **Hydrothermal Liquefaction**
  (~20 MPa and ~375° C)
- **Hydropyrolysis**
  (1-5 MPa (H_2) and ~ 375° C)

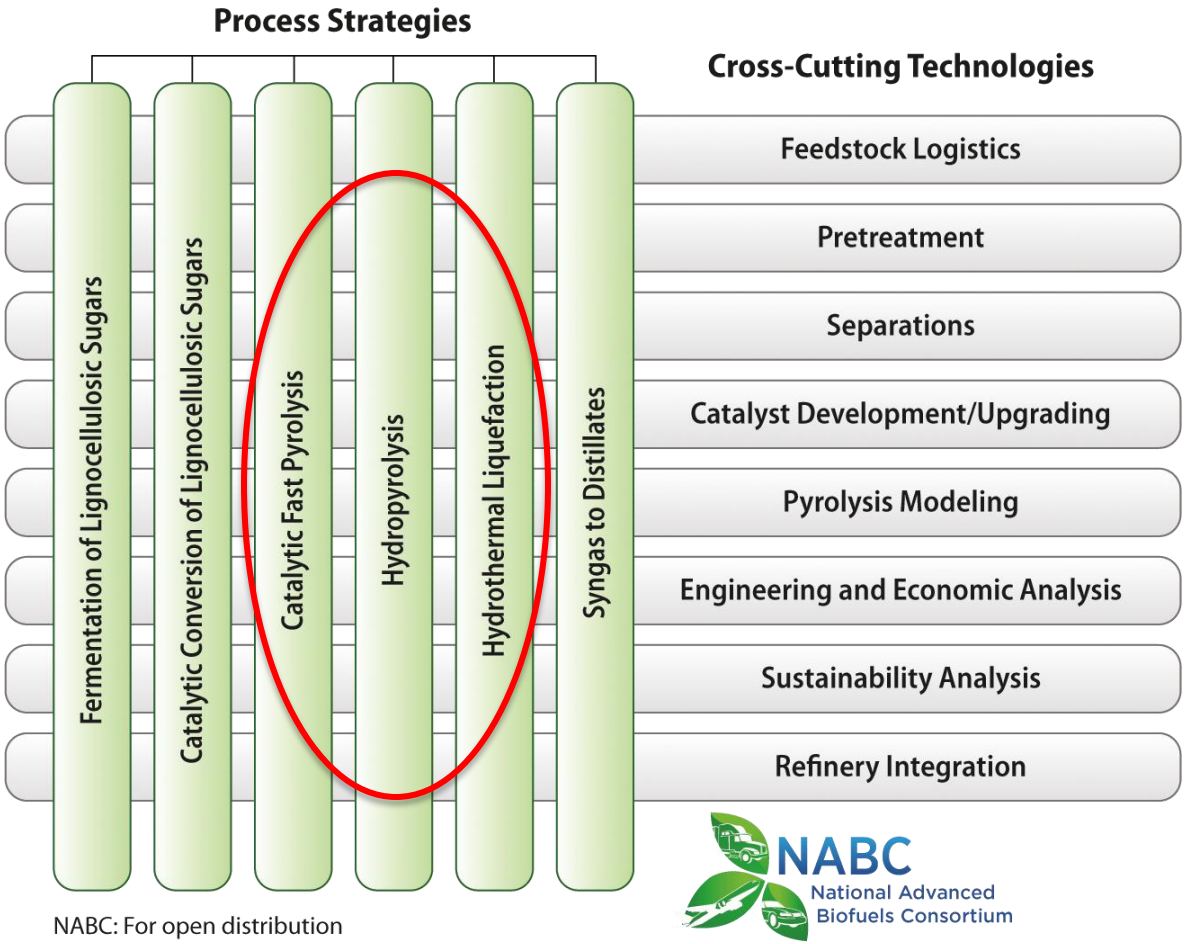
Biomass Fast Pyrolysis Oil (Bio-oil) Stabilization

FOA DE-PS36-08GO98018

- Bio-oil Stabilization: An Integrated Catalytic and Membrane Approach for Stable Bio-oils – UMass-Amherst
- Stabilization of Fast Pyrolysis Oils – UOP/NREL/PNNL
- Catalytic Deoxygenation of Biomass Pyrolysis Vapors to Improve Bio-Oil Stability – RTI International
- A Systems Approach to Bio-Oil Stabilization – Iowa State University
- Novel fast pyrolysis/catalytic technology for the production of stable upgraded liquids – Virginia Tech

Relevant NABC Activities

NABC matrix of technology and strategy teams will ensure development of complete integrated processes.



NABC: For open distribution

Recent Commercial Activity

KiOR

Envergent: UOP/Ensyn Joint Venture

USDOE/OBP IBR Project in Hawaii
(http://www1.eere.energy.gov/biomass/pdfs/ibr_arra_uop.pdf)

Ensyn RTP Process

4 commercial plants planned

- 500 tpd in MS
- 1500 tpd: 2 in MS, 1 in GA, 1 in TX

Key Technical Objectives

- **Maximize carbon conversion to biofuel**
- **Maximize energy recovery**
- **Minimize coke formation**
- **Produce stable intermediate bio-oil**
  - Reduce oxygenates
  - Eliminate contaminants
- **Reduce CAPEX and OPEX**
  - Minimize external H_2 consumption
  - Reduce process complexity
  - Maximize heat integration

Key Technical Barriers

- **Limited understanding of chemical and catalytic mechanisms and kinetics pertaining to the thermal depolymerization of biomass.**
  - How can we optimize process conditions and catalyst performance to maximize bio-oil yield and quality while reducing the impact of feedstock variability and impurities?
- **Limited understanding of the impact of the physical and chemical properties of bio-oil on downstream upgrading processes.**
  - How can the thermal stability of bio-oil be improved and impurities be removed to facilitate economical upgrading to biofuels?
- **Petroleum refining processes are not optimized for hydrocarbon liquids with high oxygen content, like bio-oils.**
  - How can carbon efficiency be maximized during bio-oil deoxygenation?
- **The physical and chemical properties of bio-oil are not compatible with existing refinery infrastructure.**
  - How can acidic bio-oils with high moisture content be integrated into existing petroleum refineries without severely impacting boiling point distributions and materials of construction?

Critical R&D Activities

- **Fundamental studies for understanding reactions, mechanisms, and kinetics of vaporization, catalytic deoxygenation, and bio-oil stability**
- **Develop thermal stability and quality metrics for bio-oil**
  - Identify and minimize bio-oil impurities (ash elements, chlorides, water) that reduce the performance of downstream upgrading catalysts
  - Determine oxygen functionality and impurities that reduce bio-oil stability.
- **Develop improved, multi-functional heterogeneous catalysts to:**
  - Balance hydrodeoxygenation, decarboxylation, and decarbonylation pathways for minimizing oxygenate and water production
  - Maximize carbon efficiency during bio-oil production
- **Develop & demonstrate (1000 hrs) novel integrated bio-oil production processes that:**
  - Maximize carbon conversion to bio-oil
  - Reduce process complexity
  - Maximize thermal integration
  - Minimize or eliminate external H_2 consumption thus reducing both capital and operating costs

Crosscutting R&D Issues

Separations

- Gas/solid: Removing char, ash components (alkali metals, chlorides, sulfates, etc.), and catalyst fines from high temperature vapors
- Gas/liquid: Optimize vapor condensation and maximize aerosol collection
- Liquid/solid: removing char and catalyst fines from bio-oil intermediates to minimize upgrading catalyst fouling
- Liquid/liquid: Separate organic hydrocarbons from aqueous stream

Technoeconomic Analysis

- Process optimization, integration, and intensification
- Capital and operating cost estimates for comparative evaluation of processes
- Determine cost-effective integration with refinery operations

Lifecycle Assessment

- Greenhouse gas reductions for advanced and sustainable biofuels technologies

Crosscutting R&D Activities

- **Investigate novel separation technologies to minimize the impact of destabilizing components**
- **Develop standard analytical laboratory procedures for product characterization**
- **Determine mechanisms of bio-oil corrosion on materials and the species formed under ambient and reaction conditions**
- **Explore selective fractionation or solvent extraction methods to isolate stable bio-oil components for upgrading**
- **Develop process models (TEA/LCA) to identify game changing technology and evaluate economic tradeoffs for process options and integration opportunities**