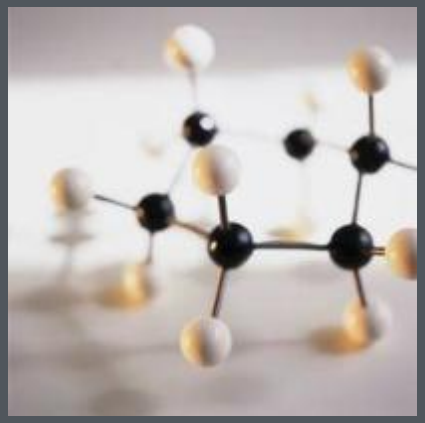
Conversion Technologies for Advanced Biofuels – Bio-Oil Upgrading

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



Report-Out Webinar

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B.S. in Chemistry
from Montana State University
M.B.A. in Operations and Systems Analysis
from the University of Washington

- Over 37 years of project management and research experience in biomass thermochemical conversion R&D involving biomass liquefaction and bio-oil upgrading.
- Manage projects related to biomass fast pyrolysis, hydrothermal liquefaction and gasification and catalytic upgrading of bio-oils.
- Focus on process development activities and underlying science for biofuels production.

Biomass Liquefaction Technology

➢ Fast Pyrolysis

- 1 atm
- 500ºC
- High throughput
- High yield (74% of C)
- Low quality oil
- Dry biomass
- Next generation
  - Catalytic pyrolysis
  - Hydropyrolysis

low capital

➢ Hydrothermal Liquefaction

- 200 atm
- 350ºC
- Low throughput
- Moderate yield (53% of C)
- Moderate quality oil
- Wet biomass
- Variations
  - Solvent liquefaction
  - Reductive liquefaction

high capital

➢ Hydroprocessing

- 50-100 atm
- 80-410ºC
- Significant capital

❖ *Variations*

↓ Low temperature for stabilization

↔ Moderate severity for partial deoxygenation

↑ High severity for hydrocarbon fuels

Current Efforts in Upgrading

- **Pyrolysis Core R&D**
  - Bio-oil hydrotreating (numerous feedstocks)
  - Bio-oil analysis
- **National Advanced Biofuels Consortium**
  - Hydrothermal liquefaction (of lignocellulosics) and product hydroprocessing
- **National Alliance for Advanced Biofuels and Bio-products**
  - Hydrothermal liquefaction (of algae) and product hydroprocessing
- **Bio-oil Upgrading (numerous feedstocks)**
  - Fast pyrolysis hydrotreating reactor/catalyst improvements
  - Catalytic pyrolysis and hydrotreating
  - Catalytic hydropyrolysis
- **IBR (numerous feedstocks)**
  - Fast pyrolysis and hydroprocessing
  - Catalytic hydropyrolysis

Barriers to Selective Fractionation

- **Process Integration**
  - Lack of understanding of what we need and want to separate in the fractionation step
  - Lack of understanding: impact of downstream/upstream processing, including integration into a petroleum refinery
- **Characterization of bio-oil intermediates**
  - A need for new methodologies and standards for chemical and physical characterization of fractions
- **Corrosion of Structural and Handling Materials and Metallurgy**
- **TEA/LCA**
- **Demonstration**

Critical R&D for Selective Fractionation

Process Integration

- Indentify applications for the fractions and develop fractionation approaches
- Explore opportunities for downstream processing which could include fermentability of products
- Evaluate site specific requirements for feedstock source and refinery customers

Characterization of bio-oil intermediates

- Improve chemical analysis of bio-oil and fractions – new methods development
- Develop standardized oils from labs/industrial leaders for analysis

Barriers to Destabilizing Component Removal

- **Components**
  - Unknown identity of destabilizing components
- **Metrics**
  - Lack of criteria to define "stability" of a bio-oil (e.g., change in viscosity, O-content, residual loss on heating, TAN)
  - Unknown acceptability level for stability
- **Chemistry**
  - Need for understanding of destabilizing chemistry
  - Understanding the complex interactions amongst components
- **Separations**
  - How to efficiently separate destabilizing components from stable components
- **Materials—Demonstration—TEA/LCA**

Critical R&D for Destabilizing Component Removal

➢ Components

- Identify and characterize categories of components for their potential impacts on stability
- Evaluate the effect of operating variables on formation and fate of destabilizing components

➢ Metrics

- Evaluate applicability of petroleum standards for bio-oils and modify where needed

➢ Chemistry

- Systematic study of component concentration vs. aging and chemical properties
- Determine the optimal point(s) to remove components (e.g., front, middle, back, local vs. central)
- Determine how TAN is related to and impacts stability of intermediates, catalyst performance, materials/equipment

Critical R&D for Destabilizing Component Removal

- **Separations**
  - Compare separation technologies
  - Determine effect of bio-oil chemical properties on membranes (particle fouling, acidic nature)
  - Evaluate staged condensation of bio-oil fractions
  - Evaluate targeted biomass harvesting to decrease composition of destabilizers due to seasonal fluctuations in composition
  - Perform fundamental and pilot research for char removal/filters and membranes

Barriers to Chemical Composition Modification

- **Catalysis**
  - Understanding the mechanistic basis for catalyst fouling and deactivation
- **Hydrogen Considerations**
  - High cost of hydrogen and means of production and recycle systems
- **Refinery Integration and Specifications**
  - Establishing minimum requirements for acceptable refinery inputs at specific points of integration
- **Improved Processes**
  - Need a novel, non-hydroprocessing (non-conventional) upgrading technology
- **Supply Chain Robustness – Bio-oil Analysis**

Critical R&D for Chemical Composition Modification

Catalysis

- Develop protocols for operating in the presence of destabilizing components and contaminants
- Develop poison and corrosion tolerant or easily regenerable catalysts that can maintain high C yields

Hydrogen Considerations

- Engineer internal hydrogen production capabilities such as from aqueous waste streams
- Explore novel non-H_2 intensive and/or non-catalytic routes

Refinery Integration and Specifications

- Understand refinery insertion point requirements/specifications
- Analyze the impact of finished fuel and new specs for biofuels

Improved Processes

- Produce low cost, low tech upgrading for distributed systems

Crosscutting R&D Issues:

- **Materials**
  - Need for low(er) cost, corrosion resistant materials of construction (i.e., cheaper than stainless steel)
  - Detail mechanisms of bio-oil corrosion on materials and the species formed under ambient and reaction conditions

- **Demonstration**
  - Need for demonstration at-scale to attract investors and financing
  - Lack of robust data set to show and convince refineries that bio-oil is compatible with their systems (>1000 hr continuous operation

- **Produce a database of bio-oil chemical composition based on such variables as:**
  - Feedstock,
  - Type of process,
  - Process conditions

Crosscutting R&D Issues:

➢ TEA/LCA

- Lack of information about impact on cost of final product
- Sustainability metrics for bio-oil processing
- Systems optimization--identify optimal point in process to remove contaminants
- “Solutions” need to be vetted across the value chain (refineries, pipelines, end-users [engine manufacturers], environmental regulators)
- Program to analyze and classify “removed streams” and development of treatment options for recovery of byproducts from waste streams
- Upfront TEA before bigger R&D investment