



*Summary of Key Take-Aways: IBR
Optimization and Alternative Jet Fuel
Workshops*

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Outline

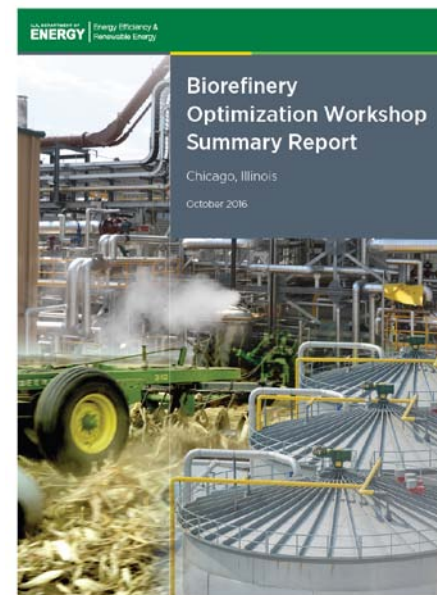
- Tiger Team
- Biorefinery Optimization Workshop
- Alternative Jet Fuel Workshop
- IBR Optimization FOA
- What's next?

BETO ADO Strategy

- The March 2016 RFI and Tiger Team initiatives sought information on technical and operational challenges that have hindered, or possibly hinder in the future the achievement of reliable continuous operation of Integrated Biorefineries.
- Stakeholder responses showed that the **greatest impact** would come from addressing solids handling operational issues such as the ability of achieving reliable feeding into pre-treatment systems as well as the conveying of solids into pressurized reactors.
- Additional topics cited were the exploration of opportunities for monetization of intermediates and mitigation of operational challenges due to repurposing of equipment used from other similar applications.

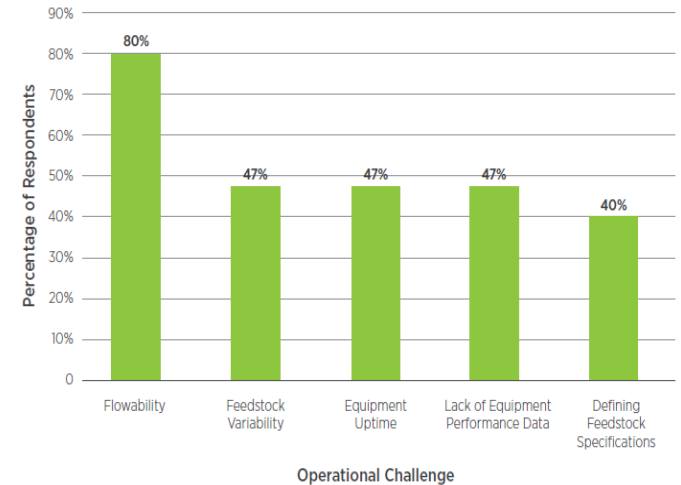
IBR Optimization and Alternative Aviation Fuels Workshop

- Workshop held October 5-6, 2016 in Chicago, IL
 - Attended by over 100 stakeholders from government, industry, and academia
 - Three breakout sessions:
 - Feedstock and Materials Handling
 - Process Scale-Up, Intensification, and Cost Reduction
 - Co-Product and Waste Stream Monetization
- Workshop held September 14-15, 2016 in Macon, GA
 - Attended by stakeholders from government, industry, and academia
 - Four breakout sessions:
 - Economic and Technical Competitiveness
 - Fuel Conversion and Scale-up
 - Environmental Sustainability and Life-cycle Benefits
 - Feedstock and Product Supply Chains



Feedstocks and Solids Handling Challenges

- Feedstock uniformity/variability and its impact on the utilization of a biorefinery
- Feedstock variance/Particle size/Geometry impact on process design and projected maintenance
- Quality assurance/preprocessing standards for feedstocks.
- Lignocellulosic feedstock's low density and costly transport on a \$/ton basis.
- Quality degradation over time in storage
- Design safety and standards, particularly for feedstock size reduction and dust removal
- Inherent fire risk at storage facilities.
- Conversion processes and the heterogeneity or modification of characteristics of the biomass



Stakeholder's Feedstocks and Solids Handling Recommendations

- **Modeling Tools**
 - Develop modeling or simulation tools to allow directional guidance on materials and unit operations
 - Expand database for physical and mechanical properties of various feedstock
- **Feedstock Quality Measurements and Standards**
 - Expand the knowledge base on the subjects of solids handling
 - Enhance bulk solids measurement techniques
 - Address solids handling operational issues such as the ability of achieving reliable feeding into pre-treatment systems as well as the conveying of solids into pressurized reactors
- **Equipment Improvements**
 - Publish an equipment engineering “handbook” for biomass materials. Identify correlations between biomass material properties and equipment design and performance parameters.

Scale-Up, Conversion, Intensification, and Cost Reduction/Economic and Technical Competiveness Challenges

- Design
 - Dealing with improperly designed equipment based off of lab data
 - Operating with insufficient data from improper piloting
 - Erosion and corrosion of reactor vessels, heat exchangers, and valves
 - Lack of robust simulation models and life-cycle analyses that take uncertainty into consideration
- Conversion
 - Dealing with changes in conversion efficiency after scaling to demonstration scale
 - Removing biomass contaminants that can deactivate biological catalysts or produce a contaminated co-product
- Business:
 - Understanding the balance between the economic feasibility and environmental impact

Stakeholder's Scale-Up, Conversion, Intensification, and Cost Reduction/Economic and technical Competiveness Recommendations

- **Pilot Scale facilities:**

- Develop an operational pilot-scale (or larger-scale) facility that is open to biorefinery project planners that will help to **reduce cost and improve overall efficiency** and productivity
- Continue to **support the reduction of scale-up costs** all the way from feedstock production through driving down the cost of conversion with R&D improvements.

- **Simulation Models/Conversion:**

- Develop robust simulation models and life-cycle analyses that take uncertainty into consideration
 - Need to consider designs and estimate at **current scales** (i.e., 500 tons/day or smaller)
- Encourage fuel producers to investigate a range of feedstock options and to consider developing **feedstock agnostic conversion** strategies.
- To support processes that focused on low aromatic jet fuel production strategies to improve the air emission impacts of AJF blendstocks.
- Utilize carbon from all waste streams(**no wasted carbon**) to help improve carbon efficiency and better overall economics

- **Public Outreach:**

- Develop initiatives and mechanisms that enable end users and fuel manufacturers to collaborate more frequently
- Work with ASTM and other organizational groups to help streamline the certification process and **reduce the burden** for the approval requirements.
- Need further **public outreach and education** on the benefits (e.g., societal and economic) and technical feasibility of AJF

Environmental and Sustainability and Life-Cycle Benefits Challenges and Recommendations

- Estimated sustainability metrics (primarily GHG estimates) are not consistent due to wide variations in the assumptions that are utilized in these analyses.
- There is need for further support from BETO to develop a **consistent approach** to analysis.
- Need to understand how the impacts of co-products and LUC (both direct and indirect) affect LCA estimates
- Need to evaluate the implications of assumptions around “upstream” elements of the life cycle and outline the appropriate time scale for assessing impacts of GHG emissions (100 years, 20 years, etc.).

IBR Optimization FOA

Four Topic Areas:








1. Robust, continuous handling of solid materials (dry and wet feedstocks, biosolids, and/or residual solids remaining in the process) and feeding systems to reactors under various operating conditions
2. High value products from waste and/or other under-valued streams in an integrated biorefinery
3. Industrial separations within an integrated biorefinery
4. Analytical modeling of solid materials (dry and wet feedstocks, and/or residual solids remaining in the process) and reactor feeding systems

Funding:

- DOE share of up to **\$19.8 million**
- **USDA-NIFA** share of up to **\$2.9 million**
- Period of Performance – 36 months

Recently Selected Integrated Biorefinery Optimization Projects

On September 20th DOE selected eight projects to negotiate for up to **\$15 million** in total DOE funding to optimize integrated biorefineries. These projects will work to solve critical research and developmental challenges encountered for the successful scale-up and reliable operations of integrated biorefineries (IBRs), decrease capital and operating expenses, and focus on the manufacture of advanced or cellulosic biofuels and higher-value bioproducts.

| | |
|--|---|
| <p>Topic Area 1</p>  | <p>ThermoChem Recovery International, Inc.</p> |
| <p>Topic Area 2</p>    | <p>Texas A&M Agrilife Research</p> <p>South Dakota School of Mines</p> <p>White Dog Labs</p> |
| <p>Topic Area 3</p> | <p>No Selection</p> |
| <p>Topic Area 4</p>    | <p>National Renewable Energy Laboratory</p> <p>Clemson University</p> <p>Purdue University</p> <p>Forest Concepts</p> |

Questions?

Thank You!

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Additional Slides

Improved Feeding and Residual Solids Recovery System for IBRs

Location: Baltimore, Maryland

Technology Summary

- TRI will study and **improve feedstock and residual solids handling systems** targeted to commercial pyrolysis and gasification reactors.
- TRI's work in these systems will **promote feedstock flexibility** and enable the **processing of low-cost feedstock** to enhance IBRs' economic viability.



Multi-stream Integrated Biorefinery Enabled by Waste Processing

Location: College Station, Texas

Technology Summary

- Texas A&M will work on achieving a multi-stream integrated biorefinery (MIBR), where **lignin-containing IBR waste** will be fractionated to produce lipid for **biodiesel, asphalt binder modifier, and quality carbon fiber**.
- The MIBR will improve IBR sustainability and cost-effectiveness.



Upgrading of Stillage Syrup into Single Cell Protein for Aquaculture Feed

Location: New Castle, Delaware

Technology Summary

- White Dog Labs' project will use the residual cellulosic sugars in cellulosic stillage syrup to **produce single-cell protein (SCP)** for aquaculture feed.
- Currently, the syrup content is used for biogas production and as the solid fuel for boilers.
- The SCP is a **higher-value product** that could be generated from an **existing stream** and could enhance the economic feasibility of IBRs.



Pilot Scale Biochemical and Hydrothermal IBR for Cost-effective Production of Fuels and Value Added Products

Location: Rapid City, South Dakota

Technology Summary

- The South Dakota School of Mines will demonstrate the cost-effective production of **biocarbon, carbon nanofibers, polylactic acid, and phenol** from the **waste streams** generated from the biochemical platform technology.
- These products will **generate revenue** for IBRs and help **lower the fuel cost** from these facilities.



Integrated Computational Tools to Optimize and De-Risk Feedstock Handling & High-Pressure Reactor Feedings Systems: Application to Red Rock Biofuels' Biorefinery

Location: Golden, Colorado

Technology Summary

- NREL will leverage and extend state-of-the-art modeling and simulation tools to develop integrated simulations for feed handling and reactor feeding systems.
- The experimentally validated simulation toolkit will be generalized to aid in optimizing and de-risking biomass conversion processes that use these common feed handling and reactor feeding units.
- The toolkit will also provide correlations to adjust optimal operating conditions based on feedstock parameters.



Integrated Process Optimization for Biochemical Conversion

Location: Clemson, South Carolina

Technology Summary

- Clemson University will develop **analytical tools** to identify an **optimal IBR process design** for the reliable, cost-effective, sustainable, and continuous **feeding of biomass feedstocks into a reactor.**

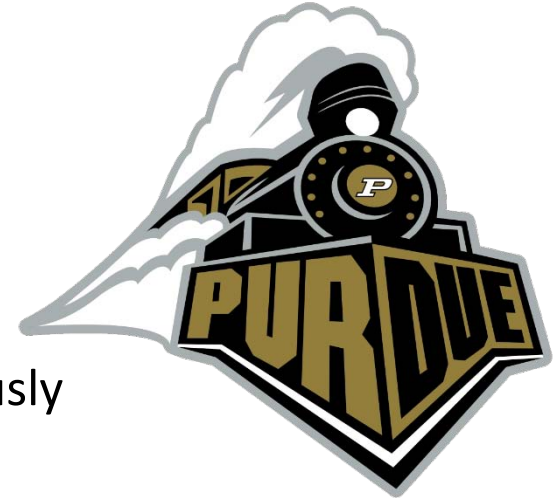


Analytical Modeling of Biomass Transport and Feeding Systems

Location: West Lafayette, Indiana

Technology Summary

- Purdue aims to develop strong, innovative **computational and empirical models** that rigorously detail the multiphase flow of biomass materials.
- Purdue will **characterize physical, structural, and compositional properties** of biomass feedstocks, and compare results of these models with **actual flow behavior** of biomass materials within a biorefinery.



Improved biomass feedstock materials handling and feeding engineering data sets, design methods, and modeling/simulation tools

Location: Auburn, Washington

forestconceptsTM
research&development

Technology Summary

- Forest Concepts proposes to develop **robust feedstock handling modeling and simulation tools** based on systematic analysis.
- The team will develop and validate a comprehensive computational model to **predict mechanical and rheological** behavior of biomass flow to enable reliable design of biomass handling systems.