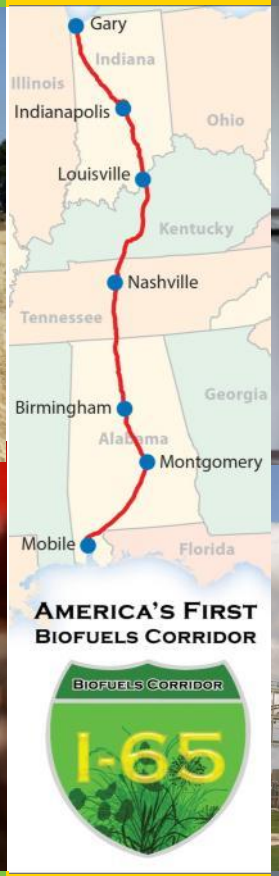
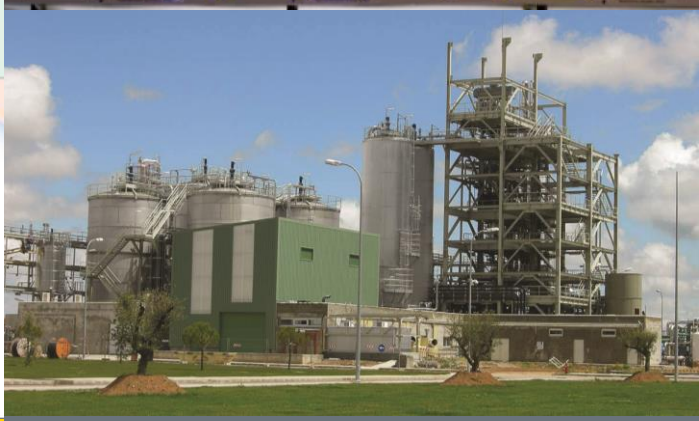
2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

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





Integration and Scale Up

WBS# 3.3.1.13

May 22, 2013

Mark Davis and Esther Wilcox

Technology Area Review: Bio-Oils

Organizations:
National Renewable Energy Laboratory

Goal Statement

Project Goal:

Demonstrate/validate the individual unit operations along with integrated production of cost competitive hydrocarbons at the pilot scale

Objectives

- Construct a flexible integrated pilot plant capable of fast pyrolysis, in situ, and ex situ catalytic fast pyrolysis
- Evaluate the performance of all unit operations including state-of-the-art analytical techniques to quantify key contaminants and chemical components
- Validate TEA projections through integrated operations
- Provide data to techno-economic analysis (TEA) models

Quad Chart Overview

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Timeline

- Project start: 2013
- Project end: 2022
- 5% complete

Budget

- Funding for FY 2012 0
- Funding for FY 2013 $2.1MM
- FY 2014 projected budget $3.0MM (operating) $2.5MM (Capital)
- Average yearly funding 1year@$2.1MM

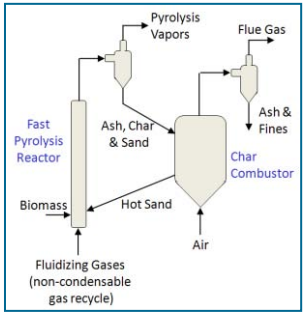
Barriers

- Tt-E. Liquefaction of Biomass and Bio-Oil Stabilization
- Tt-G. Fuel Synthesis and Upgrading
- Tt-K. Bio-Oil Pathways Process Integration

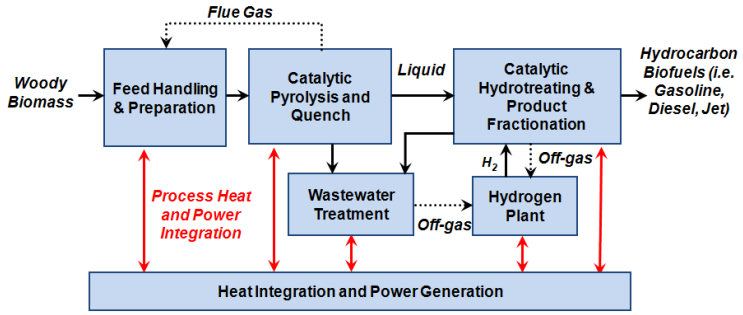
Partners

- Johnson Matthey (catalyst development)

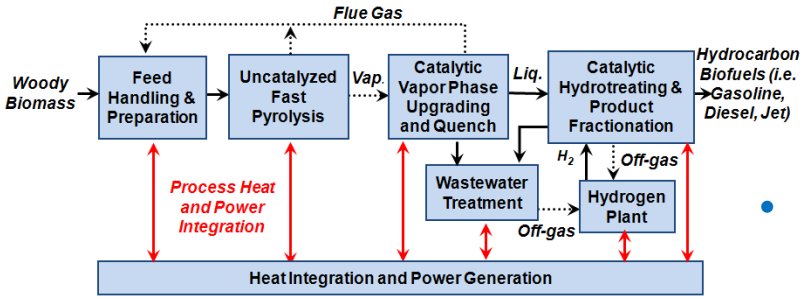
Project Overview



Fast pyrolysis



In-situ fast pyrolysis



Ex-situ fast pyrolysis

- Reconfigure existing pilot plant to develop capabilities for evaluating unit operations, catalysts, and products from different process configurations (FY14)
- Evaluate individual unit operations and catalysts. Provide data for pathway down select for FY17 demonstration (FY15)
- Finalize process design and integrate unit operations for demonstration (FY16)
- Perform integrated demonstration of unit operations demonstrating that technical targets can be achieved at the pilot scale. Provide data for techno-economic analysis demonstrating cost competitive hydrocarbons fuels (FY17) (Tt-K. Bio-Oil Pathways Process Integration)
- Management Approach: DOE-approved Project Management Plans detail schedules /milestones/risk abatement

1 - Approach

Technical Approach: Mimic commercial process model to demonstrate integrated process performance of key unit operations based on a conceptual design at the pilot scale

- TCUF pilot plant reconfigured for pyrolysis experiments based on unit operations identified in design reports and results of National Advanced Bioenergy Center (NABC).
- Final integrated design based on FY15 downselect and choice of formulated feedstock.
- Close interaction with catalyst design tasks to ensure proper reactor designs and integration.

2 - Technical Accomplishments/ Progress/Results

Milestone ID	Level (Joule, D, etc)	Title/Performance Measure	Planned Completion Date
C.DL.1	DL	An NREL technical report based on a literature review of bio-oil and upgraded bio-oil fractionation with recommendations for pilot implementation will be submitted. (Task 3)	12/31/12
A.DL.1	DL	A process hazard analysis and HAZOP will be completed and a report written outlining the action items needed to do pyrolysis vapor upgrading in the TBRF. (Task 1)	03/31/2013

- Conclusion of literature study
  - large-scale application is technically challenging
  - recommended separately controlled biomass pyrolysis and upgrading steps to yield stable blend for conventional refineries/conventional distillation
- Currently performing a corrective action plan based on a recent safety incident
  - Potential static electricity in condensation unit operation
  - A more thorough process hazard analysis on scrubber through the thermal oxidizer unit operations

3 - Relevance

- Addresses Thermochemical Conversion R&D Strategic Goal: *"Develop technologies for converting feedstocks into **cost-competitive** commodity liquid fuels such as renewable **gasoline, jet fuel, and diesel*** and achieve a minimum fuel selling price of $3/gallon of gasoline equivalent
  - Validates unit operations, integrates processes, and demonstrates technologies required to convert biomass to stable intermediates or hydrocarbon fuels. Performance targets guided by techno-economic analysis of R&D results
- Project addresses biomass conversion pathways in the MYPP:
  - M X.17: Demonstrate and validate bio-oil production to a stable intermediate (X = feedstock pathway number)
- Contributes to BeTO portfolio of biomass conversion pathways:
  - Potential to demonstrate/validate unit operations for fast pyrolysis, *in situ*, and *ex situ* catalytic pyrolysis

4 - Critical Success Factors

Success Factors

- Achieving steady state operation (0.5 ton/day) as an integrated pilot plant that meets technical targets at each unit operation
- Providing process data for techno-economic analysis for time periods that are commercially relevant
- Higher carbon efficiencies and products with more stable properties
- Dissemination of information to laboratory and industrial partners
  - Optimize performance by combining process improvements with feedstock and catalyst improvements

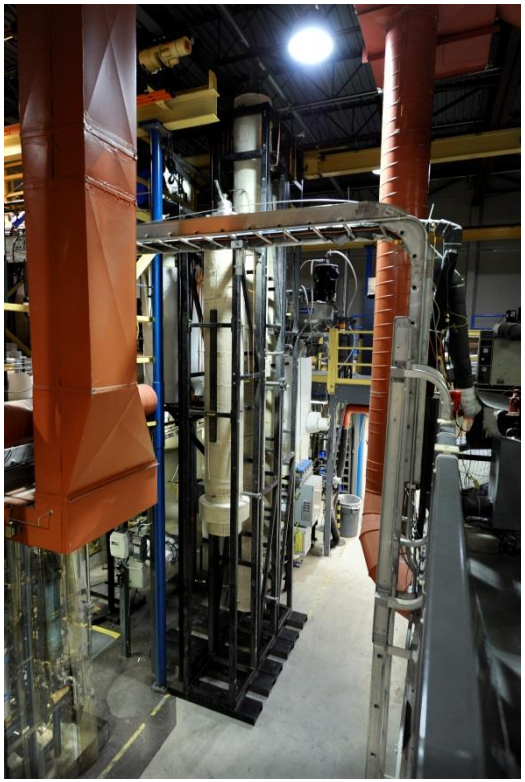
Challenges

- Robust analysis of all products and detection of relevant catalyst poisons
- Demonstrate closure of mass balance across multiple unit operations from feed to product recovery
- Early identification of unit operations based on FY15 downselect.

5. Future Work

Remainder of FY13, 1st quarter of FY14:

- Complete corrective actions, which focus on safety from the scrubber system through the thermal oxidizer unit operations, and implement a management of change process
- Complete scope of work for Lanzatech project (Competitively funded project)
- Produce bagasse pyrolysis oil for Petrobras CRADA (International Project)
- Install hot gas filter and produce pyrolysis oils for PNNL
- Computational modeling of regenerating recirculating reactor (R^3) system for catalytic fast pyrolysis



5. Future Work

Reconfiguring R^3

- Flow in riser must be sufficient to carry all material through reactor with short residence time
- Evolution of vapors from biomass must be considered
- Must be balanced with regeneration
- Computational Fluid Dynamics simulations will be used to help optimize operation
- Modeling conducted in Computational Pyrolysis Consortium

5. Future Work

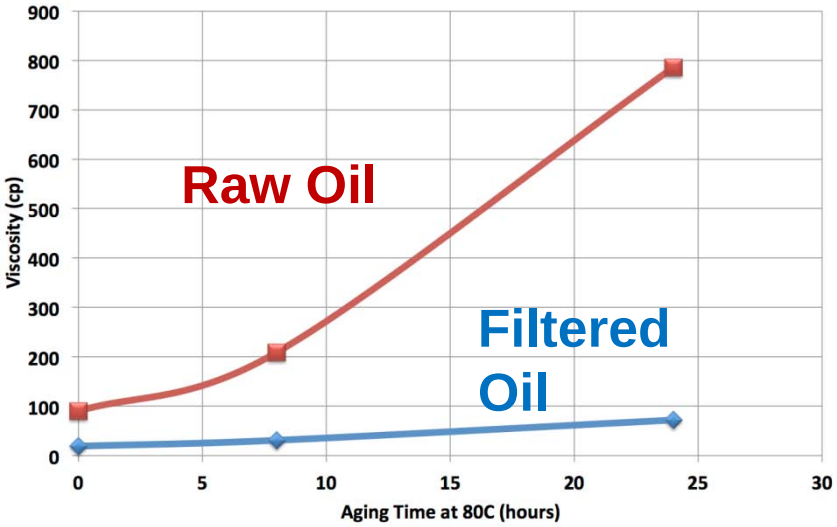
2nd Quarter FY14 through 1st Quarter FY15:

- Focus on safety and capital improvements per FY14 capital plan. Includes evaluating hazards and infrastructure, improving the alarm and warning systems, construction of new control room (NREL internal funds), improving documentation
- Capital improvements include the online analytical systems, scrubber system, R^3 improvements, cyclone redesigns, various infrastructure improvements including upgrading the electrical systems. Installation of the new thermal cracker

FY15

- Commissioning, testing, and shake-down of the redesigned/newly installed systems
- Demonstrate improved operation and/or oil production based on the new systems
- Evaluate the need for an improved hot gas filter system

5. Future Work



Fresh and Used (~1740 cycles) Ceramic filter element

Hot Gas Filtration

- Initial results of hot gas filtration indicate increased oil stabilization
- Greatly reduced alkali and alkaline earth metals and very low solids content
- Much improved with respect to storage and transport stability
- Total mass loss was estimated to be in the range of 10 to 30% by weight

"Bio-Oil Stabilization and Upgrading by Hot Gas Filtration" Baldwin, R.; Feik, C. Energy and Fuels (Accepted)

6. Summary

- The goal of this task is to construct a flexible integrated pilot plant capable of fast pyrolysis, in situ, and ex situ catalytic fast pyrolysis
  - Evaluate the performance of all unit operations
- Near term the task will focus on safety and capital improvements per FY14 capital plan
- Commissioning, testing, and shake-down of the redesigned/newly installed systems will begin in FY15
  - Demonstrate improved operation and/or oil production based on the new systems
  - Evaluate the need for hot gas filter filtration
- Success will be demonstrated by achieving steady state operation as an integrated pilot plant that meets technical targets at each unit operation
  - Providing process data for techno-economic analysis for time periods that are commercially relevant
- The biggest challenge will be to accurately measure mass/energy balances and demonstrate technical improvements for multiple unit operations

Acknowledgments

DOE Bioenergy Technologies Office (BETO)

Esther Wilcox
Calvin Feik
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Ray Hansen
Mike Sprague
Marc Pomeroy
Katie Gaston
Kristin Smith
Jason Thibodeaux

Additional Slides

- Responses to reviewer comments:
  - New project (no previous review)

Publications and Presentations

Baldwin, B.; Feik, C. “Bio-Oil Stabilization and Upgrading by Hot Gas Filtration" Energy and Fuels (Accepted) (funded by funds awarded in a competitive project award number DE-FG36-08GO18213)