

DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

Liquefaction of Forest Biomass to “Drop-in” Hydrocarbon Biofuels

Contract EE0005974

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Goal Statement

- Project Goal: Demonstrate solvent liquefaction as a viable pathway to stable intermediates that can be upgraded to fuel blendstocks
- Funding Opportunity Announcement DE-FOA-00005100
 - R&D, demonstration, and life-cycle evaluation and optimization of technologies for production of biofuels and biobased products
- Supports the goal of producing cost effective intermediates via liquefaction of biomass that can be upgraded to hydrocarbon transportation fuels

Quad Chart Overview

Timeline

- Project start date: Jan. 1, 2013
- Project end date: Dec. 31, 2016
- Percent complete: 54%

Barriers

- Tt-E: Pyrolysis of Biomass and Bio-oil Stabilization

Budget

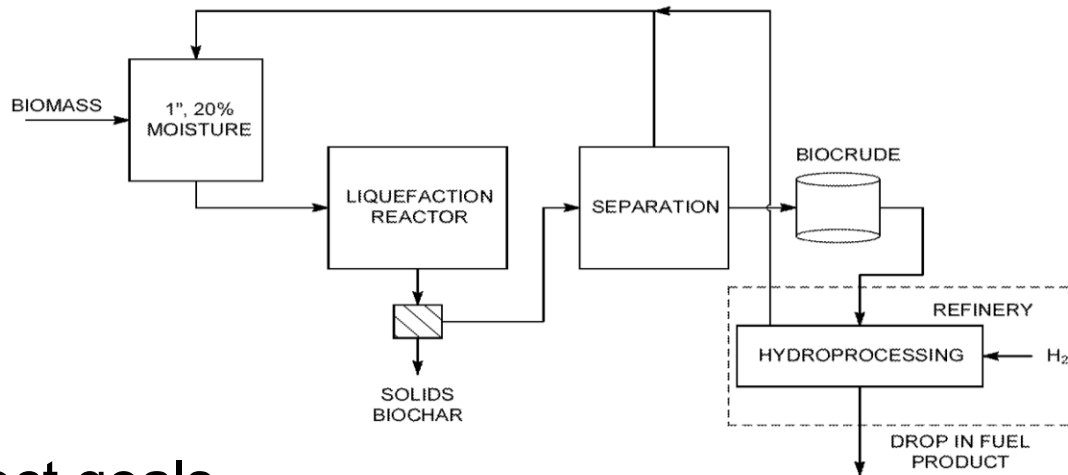
	Total Costs FY 10 –FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date)
DOE Funded*	0	0.03 M	0.68 M	2.79M
Project Cost Share (Comp.)*	0	0.17 M	0.47 M	0.24 M

*Provided by Chevron Technology Ventures – \$400k for sustainability study, \$475k for pilot plant engineering support

Partners

- Chevron Technology Ventures (CTV) has assumed contractual obligations for the project from Catchlight Energy
- CTV receiving 40% of DOE Funding, providing 100% of the cost share
- As part of CTV cost share, Weyerhaeuser and Mississippi State University contracted to study impact of feedstock production of forest biodiversity³

Project Overview



- Project goals
 - Complete proof of concept testing for Chevron’s solvent liquefaction process with solvent recycle in continuous pilot plant
 - Produce stable, deoxygenated bio-oil
 - Develop hydroprocessing conditions for upgrading solvent liquefaction bio-oil to refinery compatible biocrude and fuel blendstocks
 - Develop preliminary process design package for a demonstration plant and conduct techno-economic analysis
 - Understand biodiversity impact of biomass production on forest ecosystems
- Technical Barrier Addressed: Tt-E: Pyrolysis of Biomass and Bio-oil Stabilization

Approach (Technical)

- Proof of concept testing using small pilot solvent liquefaction unit with feed rate of 1 kg biomass/hr
- Continuous solvent liquefaction product separation and solvent recycling will be implemented and tested
- Catalysts and operating conditions for hydroprocessing solvent liquefaction bio-oil will be determined using bench scale fixed bed micro-reactors
- Operability and product quality targets
 - 8 hours continuous solvent liquefaction operation
 - Bio-oil mass yield >30%
 - Bio-oil oxygen content < 25%
 - 15 day hydroprocessing operation with production of biocrude with oxygen content < 2%

Approach (Management)

- Critical Success Factors and Potential Challenges
 - Production of thermally stable, low oxygen content bio-oil
 - Demonstration of continuous operation of key unit operations
 - Liquid separation
 - Solids separation
 - Solvent recycle
 - Cost effective hydroprocessing of bio-oil to refinery compatible biocrude
 - Sustainable source of relatively low-cost biomass
- Project Approach
 - Integrated project team of ISU engineers with thermochemical pilot plant expertise and CTV personnel with expertise in solvent liquefaction fundamental studies and pilot plant development, Process Hazard Assessment, hydroprocessing and TEA

Technical Accomplishments/ Progress/Results

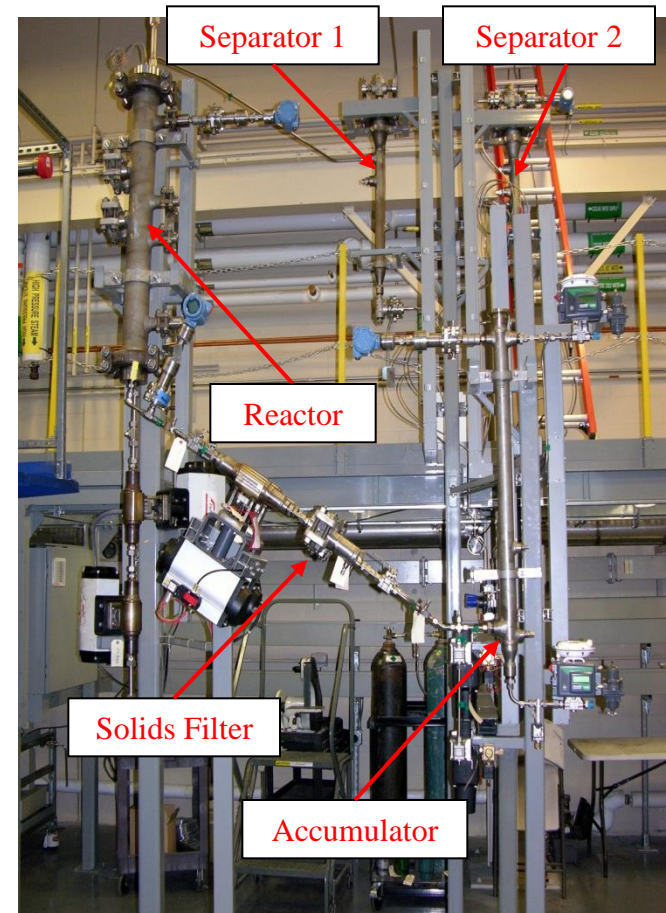
- Process & Instrumentation Diagrams and pilot plant design complete
- Process Hazard Assessment and design changes completed by ISU and Chevron
- Chevron contributed and new components integrated, pilot plant operational
- Design of solvent recycle unit operation complete and components implemented
- Mechanical shakedown of major unit operations complete
 - Feed System
 - Reactor
 - Product separation vessels
 - Solids filtration



Pilot plant products (l-r): light wood oil, heavy wood oil, light wood oil and water

Technical Accomplishments/ Progress/Results

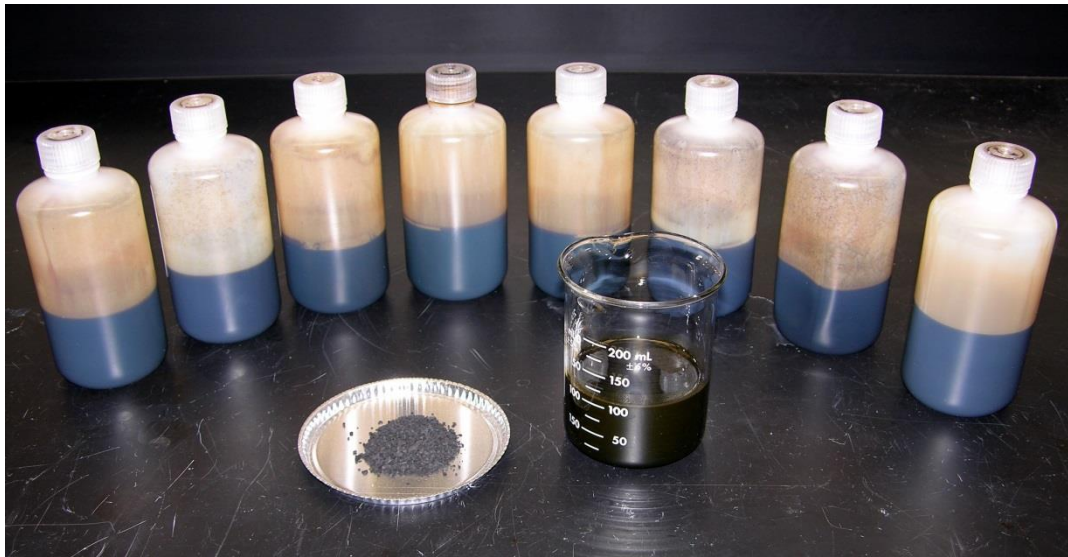
- Commissioning and operation of pilot plant with surrogate solvent system in progress



Solvent liquefaction pilot plant (left) and pressure vessel configuration (right)

Technical Accomplishments/ Progress/Results

- Laboratory scale batch Miniature Liquefaction Unit (MLU) established for concurrent research
- Two studies have commenced
 - Development of key biocrude upgrading stability metrics
 - Solvent liquefaction studies using a pyrolysis fraction produced at ISU as a potential low-cost solvent



Miniature Liquefaction Unit biocrude and char (foreground, left) samples

Technical Accomplishments/ Progress/Results

- Three year sustainability study nearly complete
- Completed by Weyerhaeuser and Mississippi State University (Contracted by CTV)
- Researched impact of increased biomass harvesting from control pine stands and pine stands intercropped with native switchgrass
 - Water quality
 - Biodiversity (breeding bird communities and nesting activity, plant community diversity, biomass production, invertebrate communities and white-tailed deer forage production)
 - Soil productivity
- Reduction in snags in intercropped sites the only significant difference from control sites
- Intercropping appears to be sustainable

Relevance

- Supports the goal of producing a deoxygenated, stable bio-oil with desirable qualities for making hydrocarbon transportation fuels in the gasoline, diesel, and jet range at less than \$3 per gallon
 - Production of clean, low-cost bio-oil that can be integrated into a biorefinery to produce fuels
 - Development of cost-effective hydroprocessing conditions to convert bio-oil to fuel blendstocks
 - Identification of large, sustainable supply of high quality biomass
- Improves commercial prospects of biomass-based transportation fuels helping to meet EISA RFS goals
- Demonstration of continuous operation of bio-oil production with solvent recycle and solids removal critical to determine feasibility of the technology

Future Work

- Commissioning of direct solvent recycle unit operation
- Continuous operation of pilot plant demonstrating fractionation of product into desired cuts, direct solvent recycle and online solids removal
- Bio-oil hydroprocessing to refinery compatible biocrude
- Development of preliminary process design package and TEA
- Remaining milestones
 - Four hours of continuous steady state operation while fractionating product into desired cuts (Q2, 2015)
 - Complete lab-scale studies to define bio-oil stability metrics (Q3, 2015)
 - Eight hours of continuous steady state operation producing bio-oil with <25% oxygen (Q4, 2015)
 - Fifteen day hydroprocessing run while producing biocrude with <2% oxygen (Q4, 2016)
 - Complete preliminary process design for demonstration plant (Q4, 2016)

Summary

- Solvent liquefaction is a promising pathway to low cost, stable intermediates for drop-in hydrocarbon fuels
- This project will demonstrate continuous solvent liquefaction, product separation with direct solvent recycle and online solids removal
- Mechanical shakedown of pilot plant reactor, liquid product separation and collection and solid filtration complete
- Key remaining challenges include demonstration of continuous operation with direct solvent recycle and online solids removal

Additional Slides

Responses to Previous Reviewers' Comments

- Comment: Why is the sustainability study included and what is the cost?
- Response
 - Represents \$400,000 of cost share
 - CTV contracted Weyerhaeuser and Mississippi State University to complete the study
 - Purpose of the study is to raise concerns about sustainability of increased biomass harvesting and production via intercropping

Responses to Previous Reviewers' Comments

- Comment: Level of commitment from Chevron and Weyerhaeuser unclear, moving toward commercialization may be problematic
- Response
 - CTV assumed contractual obligations for the project from Catchlight Energy
 - CTV providing 100% of the cost share for the project (\$875,000)
 - CTV leading hydroprocessing and sustainability tasks, co-leading preliminary process design for demonstration plant, providing significant personnel support for pilot plant task
 - Weyerhaeuser managing sustainability study

Publications

Papers

- Loman, Z. G. , S. K. Riffell, B. Wheat, D. A. Miller, J. A. Martin and F. J. Villela. *In Press* (tentative acceptance). Breeding bird community response to establishing intercropped switchgrass in intensively-managed pine stands. *Biomass & Bioenergy*.
- Loman, Z. G. , S. K. Riffell, B. Wheat, D. A. Miller, J. A. Martin and F. J. Villela. Bird community response to establishing intercropped switchgrass in intensively-managed pine stands. *Biomass & Bioenergy*, in review.
- Loman, Z. G., S. K. Riffell, D. A. Miller, J. A. Martin and F. J. Villela. 2013. Site preparation for switchgrass intercropping in loblolly pine plantations reduces retained trees and snags, but maintains downed woody debris. *Forestry* 86: 353-360.

Presentations

- Loman, Z. G., S. K. Riffell and D. A. Miller. 2013. Effects of switchgrass intercropping in early successional pine plantations on bird communities. American Ornithologists' Union-Cooper Ornithological Society Joint Meeting, Chicago, Illinois.
- Loman, Z. G., S. K. Riffell, J. Martin and D. A. Miller. 2013. Effects of switchgrass intercropping in early successional pine plantations on bird communities. Mississippi Chapter of The Wildlife Society, Jackson, MS.
- Wheat, B. R., Z. G. Loman, S. K. Riffell, S. Demarais and D. A. Miller. 2013. Biomass and deer forage response to intercropping switchgrass as bioenergy feedstock in Mississippi. 67th Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, Oklahoma City, Oklahoma.
- Wheat, B. R., Z. G. Loman, S. K. Riffell, S. Demarais and D. A. Miller. 2013. Biomass and deer forage response to intercropping switchgrass as bioenergy feedstock in Mississippi. Mississippi Chapter of The Wildlife Society, Jackson, MS.
- Riffell, S., S. P. Rupp (Committee chair), J. Verschuyt, T. B. Wigley, L. Bies, A. Glaser, C. Kowaleski, T. McCoy, T. Rentz and J. Sibbing. 2013. Effects of bioenergy production on wildlife and wildlife habitat: an overview of the TWS Technical Review and implications for forestry in the Southeast. The Role of Natural Renewable Resources in Energy Sustainability and Global Warming Mitigation: A Symposium. Maroon Edition Event, Mississippi State, MS.