DOE Bioenergy Technologies Office (BETO) 2017 Project Peer Review

Renewable Acid-hydrolysis Condensation Hydrotreating (REACH) Pilot Plant

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Technology Area Review

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Goal Statement

- Design, build, and operate a pilot plant to scale-up the Mercurius REACH™ process.
- REACH™ - a novel technology that efficiently converts cellulosic biomass into drop-in hydrocarbon jet fuel and diesel.
- Provides an economically viable technology to start building cellulosic biofuel capacity for RSF mandates.
- Competes with petroleum economics down to $40/bbl.

Advanced Biofuels Categories

Biochemical Conversion:
- Fermentation to alcohols
- Very long residence time (days)
- Requires sugars as a feedstock

Thermochemical Conversion:
- Gasification and Pyrolysis
- Vapor phase process
- Large equipment to handle vapor volumes

Liquid Phase Catalytic (LPC) Conversion:
- **Low volumes with liquid phase**
- **Fast reactions and low residence times (hours)**
- **Converts raw biomass**
- **Low temperature / pressure**

Liquid phase = smaller equipment.

+

Catalytic = faster = smaller equipment.

=

Lower capital costs.

REACH Technology

REnewable
Acid-hydrolysis
Condensation
Hydrotreating

A → CMF → C → 2-3x's → H

A → Bioproducts

Acid-hydrolysis
breaks down biomass to non-sugar intermediates.

Bioproducts

Condensation
puts molecules together to customize carbon chain length.

Hydrotreating
deoxygenates to drop-in hydrocarbon fuel.

Quad Chart Overview

Timeline

- October 1, 2013
- December 2018 (estimate)
- Percent complete ~20%

Budget

	Total Costs FY 12 –FY 14	FY 15 Costs	FY 16 Costs	Total Planned Funding (FY 17-Project End Date
DOE Funded	576k	275k	136k	3,600k
Project Cost Share (Comp.)*	576k	275k	136k	3,600k

Barriers

- Barriers addressed:
  - Not mentioned in Multi-Year Program Plan
  - High Risk of Large Capital Investments
    - Liquid Phase Catalytic = low CapEx
    - Well known already scaled processes
  - Cost of Production
    - Feedstock flexible
    - No enzymes
    - Distributive model capable
    - < $2/gal well below $3 EERE goal.

Partners

- Sub-recipients:
  - Purdue University
  - MSUBI
  - University Of Maine
- CSIRO - Melbourne

Executive Summary

1. **Original FOA (DE-FOA-0000739, Mod. 000002):**

   Identify, evaluate, and select innovative pilot- or demonstration-scale integrated biorefineries that can produce hydrocarbon fuels that meet or are likely to meet military fuel specifications (JP-5, JP-8, F-76).

2. **High-level project description: Currently planning for BP2:**
   - *Objective*: Produce volume of fuel for military testing (at scale of 1 MT feedstock per day)
   - *Feedstock*: Currently testing with corn stover. Future plans to test organic, non-recyclable portion of MSW and other non-food, waste cellulosic feedstock (e.g. yard waste)
   - *Testing Partners:*
     - Commonwealth Scientific and industrial Research Organisation (CSIRO): R&D for acid-hydrolysis and condensation reactions
     - Purdue University: condensation reactions, feedstock supply study, acid-hydrolysis reactions
     - University of Maine: condensation and hydrotreating reactions
     - Michigan State University Bioeconomy Institute (*hereafter referred to as "MSUBI"*): acid-hydrolysis scale-up, condensation products analyses

Executive Summary

3. **Provide a high-level review of the Project Team's accomplishments since the last CPR review (or since project start for new projects):**
   - *Bench scale preparatory research at CSIRO:* Acid hydrolysis with multiple feedstocks, pretreatment investigations, feed prep reactions, condensation reactions.
   - *1 Liter scale-up at Purdue:* Acid hydrolysis with multiple feedstocks, pretreatment investigations, feed prep reactions, condensation reactions at 1L scale.
   - *400 Liter scale-up at MSUBI:* Acid hydrolysis with corn stover at 400L scale.
   - *Continuous Reaction Optimization at UMaine*: Condensation reactions and hydrotreating with flow reactors.
   - *Preliminary fuel testing at Purdue and UMaine*
   - *Very high chance of success with optimized steps of the process.*
4. **Provide a high-level review of the future plans for the project:**
   - *1-10 DTPD pilot operation at MSUBI:* Use existing equipment and infrastructure to operate pilot plant for the production of condensation feedstocks. Feedstock to be supplied by Purdue.
   - *Small scale condensation and hydrotreating:* Use existing equipment and infrastructure for condensation reactions and hydrotreating at UMaine (~1 L/day).
   - *Fuel testing*: Military jet fuel and diesel testing at existing facilities at Purdue.
   - *Optional larger scale fuel production*: Produce 10's L/day at existing pilot scale hydrotreating facilities.
   - *TEA/LCA Update:* Mercurius and Purdue.
   - *Current cost structure below $2/gge fuel:* Low cost producer well below future BETO target of $3/gge.

Project Schedule Updates

1. Variance from original schedule to final schedule.
   - Preparatory work was expanded due to technology provider dropping out of the project.
   - Total schedule slip approximately 2.5 years.

2. Identify and discuss major factors for schedule delays.
   - Longer preparatory period. ~6 months.
   - Funding delays. ~12 months.
   - Administrative delays. ~12 months

Budget Overview

- Present total project cost (TPC) and total budget information
  - The proposed BP-2 budget reduced due to the use of existing equipment.
  - BP-1A (preparatory): $1.4mil vs. $0.52mil original.
  - BP-1B (FEL): $0.6mil vs. $0.86mil original.
- Original TPC = $9.4mil

1 - Project Overview

- Design, build, and operate a pilot plant to scale-up the Mercurius REACH™ process and provide fuel for certification testing.
- Started award negotiations, April 2013, DOE kick-off June 2013, contract in place Oct 2013.
- Completed BP-1A for research optimization June 2014:
  - CSIRO small bench scale investigation of multiple steps of technology
  - Purdue scales-up acid hydrolysis to 1 L size
  - Multiple 400 L runs at MSUBI
  - Favorable IE report
  - DOE provided technical GO decision
- BP-1B nearly complete:
  - FEL engineering for Pilot Plant
  - March 31, 2017 – ***No more time extensions!!!!!!***

2 – Approach (Management)

- *Use accepted Front End Loading (FEL) project management procedures to manage project.*
- *Focus on safety especially during BP-2 activities.*
- *Reduce CapEx by re-using existing equipment and facilities.*
- *Reduce OpEx by sharing or contracting with existing/trained labor.*
- *Maximize in-kind cost share through out project.*
- *Use project successes in pitch to potential investors.*
- *Barriers – DOE 25% contingency fund requirement.*

2 – Approach (Technical)

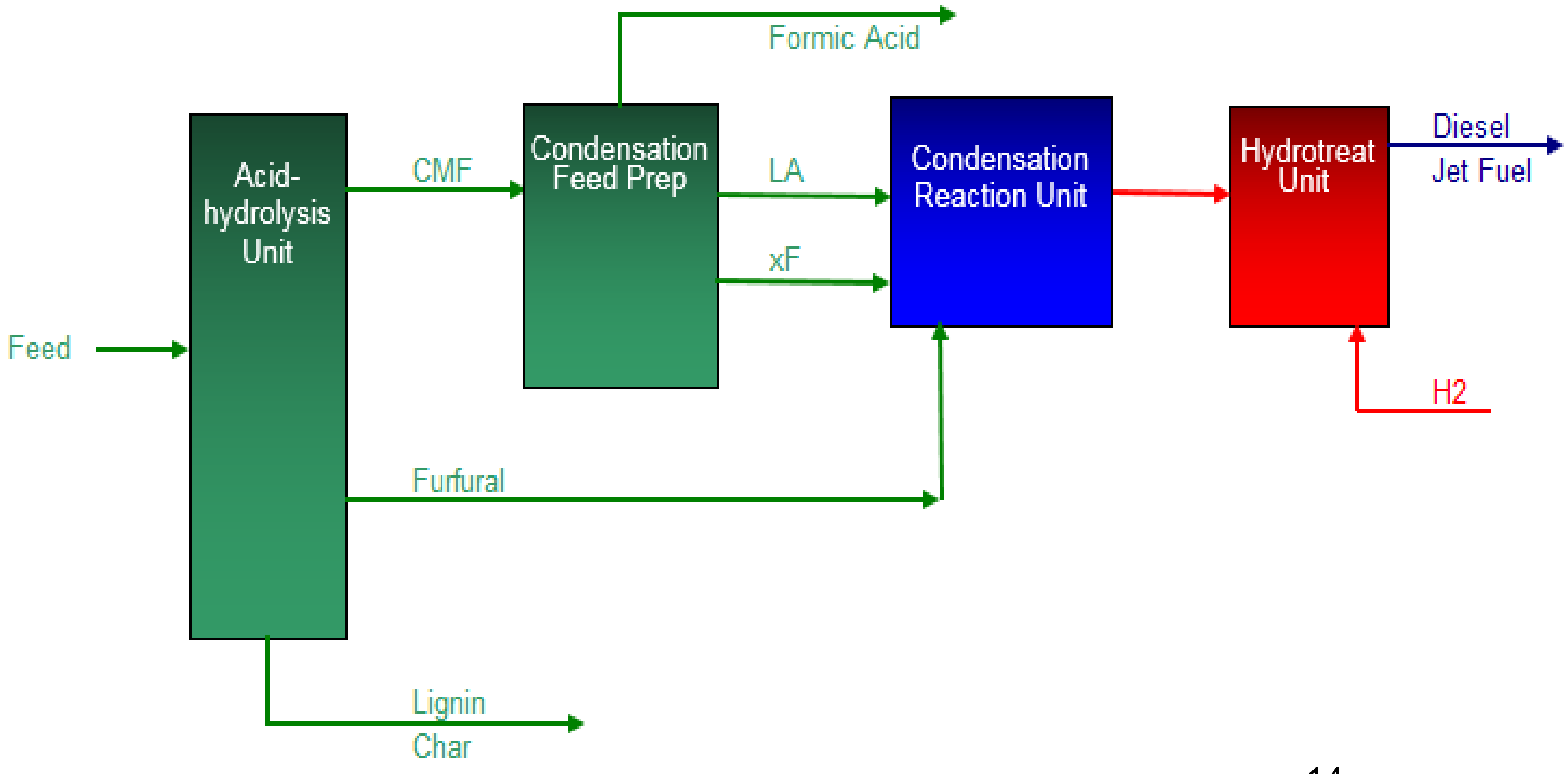
- *REACH technology is – Renewable Acid-hydrolysis Condensation Hydrotreating*
  - *Acid hydrolysis to non-sugar intermediates – CMF(converted to other compounds) and furfural.*
  - *Condensation reactions to combine intermediates for carbon chain length.*
  - *Hydrotreat to drop-in hydrocarbon jet fuel and diesel.*
- *Critical success factors:*
  - *Confirm reaction parameters, residence times, and product yields.*
  - *Confirm relative insensitivity to feedstocks.*
  - *Bench scale-up to inform pilot plant design.*
  - *Pilot runs to provide data including: catalyst life and recovery, solvent recycle, product quality; for commercial plant design.*
  - *Successful product testing for certification.*
- *Potential challenges: (technical and non-technical) to be overcome for achieving successful project results*
  - *Technical – Acid recovery/recycle, product quality, TEA validation.*
  - *Non-technical – fund raising and DOE interface issues.*

3 – Technical Accomplishments/ Progress/Results

- *Acid-hydrolysis –*
  - *Verified CMF yields with multiple feed stocks at bench scale.*
  - *Developed pretreatment to maximize furfural yields.*
  - *CSIRO data for: corn stover, hard wood, and sugar cane bagasse.*
  - *Purdue – assembled and operated 1 L pressure reactor using corn stover.*
  - *MSUBI – scaled up to 400 L with existing equipment.*
- *Condensation –*
  - *CSIRO investigated CMF conversion to levulinic compounds and identified the best path forward for pilot plant investigation.*
  - *CSIRO investigate multiple condensation pathways*
  - *Purdue investigated promising solid catalyst condensation pathway.*
  - *Purdue/UMaine scaled up both condensation feed generation and condensation reactions.*
- *Hydrotreating -*
  - *UMaine hydrotreated condensation products to hydrocarbons.*
  - *Confirmed complete deoxygenation to jet fuel and diesel range hydrocarbons.*

3 – Technical Accomplishments/ Progress/Results (cont'd)

- *Milestones – Go decision on proceeding to next budget period, BP-1B, front end engineering for pilot plant.*
- *Current optimized block flow:*



4 – Relevance

- *Lowers Capex for cellulosic biofuels*
  - *Liquid phase catalytic process inherently more capital efficient*
  - *3-5 $ per annual gallon of capacity*
  - *Pilot project will firm up Capex estimates*

- *Lowers Opex for cellulosic biofuels*
  - *Does not require enzymes for hydrolysis*
  - *Robust acid hydrolysis is feedstock flexible*
  - *Lower cost harvest and feedstock storage techniques in development*
  - *No genetically modified organisms or feedstocks required*
  - *Distributive model would lower costs further*

Cost Structure (Corn Stover)

CapEx:

$ **3–5**

/annual gal capacity

For example, a 15 mil gal plant at $4/annual gal capacity would cost $60 million

OpEx:

$ **1.06**

/gal **excluding** capital charges

$ **1.62**

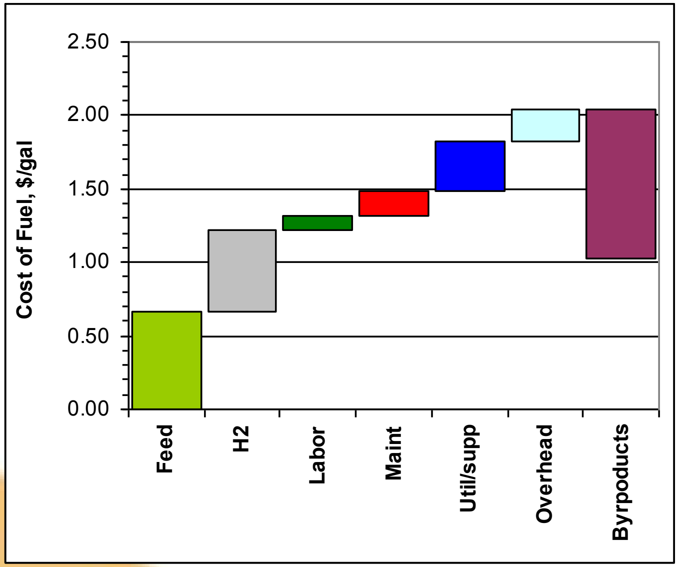
/gal **including** capital charges

Cost Breakdown

Base Case

$ **50**
/dry ton feed

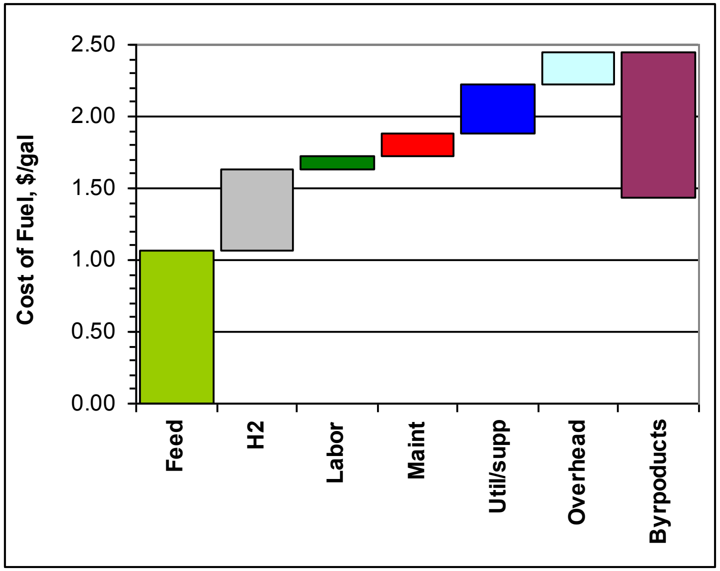
1.06
$/gal



Sensitivity

$ **80**
/dry ton feed

1.46
$/gal



5 – Future Work

- *BP-2 will start in April 2017, operate pilot plant at MSUBI*
- *After a GO decision at the end of BP-1B move into BP-2.*
- *BP-2:*
  - *Startup and operation*
  - *Investigation of multiple feedstocks, recycles, recoveries, etc.*
- *BP-3: Demo Plant*

Summary

- Early stage project that is on track to meet project deliverables and milestones.
- Successfully completed BP-1A/1B.
- Project has been very efficient and will continue to look for existing facilities and opportunities to reduce costs.
- Primary barrier to date has been fund raising.
- Potentially game-changing technology.

Thank You!

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