DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

Renewable Acid-hydrolysis Condensation Hydrotreating (REACH) Pilot Plant

March 23, 2015
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.

Quad Chart Overview

Timeline

- October 1, 2013
- December 2016 (estimate)
- Percent complete = 14%

Budget

	Total Costs FY 10 – FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date
DOE Funded	0	10k	575k	4.25 mil
Project Cost Share (Comp.)*	0	10k	575k	4.25 mil

Barriers

- Barriers addressed:
  - Does not fit in category to be 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
  - Reduces Technology Development Costs
    - No genetic research
    - Analogs in Pulp/Paper and Petroleum

Partners

- Sub-recipients:
  - Purdue University, 20%
  - University Of Maine, TBD
- CSIRO - Melbourne

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.
- Changed front-end technology provider because applicate partner refused to participate – developed in-house instead.
- DOE agreed to add a BP-1A for research optimization.
  - 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
- BP-1A technical completion June 2014:
  - Favorable IE report
  - DOE provided technical GO decision

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, techno-econ validation.*
  - *Non-technical – fund raising and DOE interface issues.*

2 – Approach (Management)

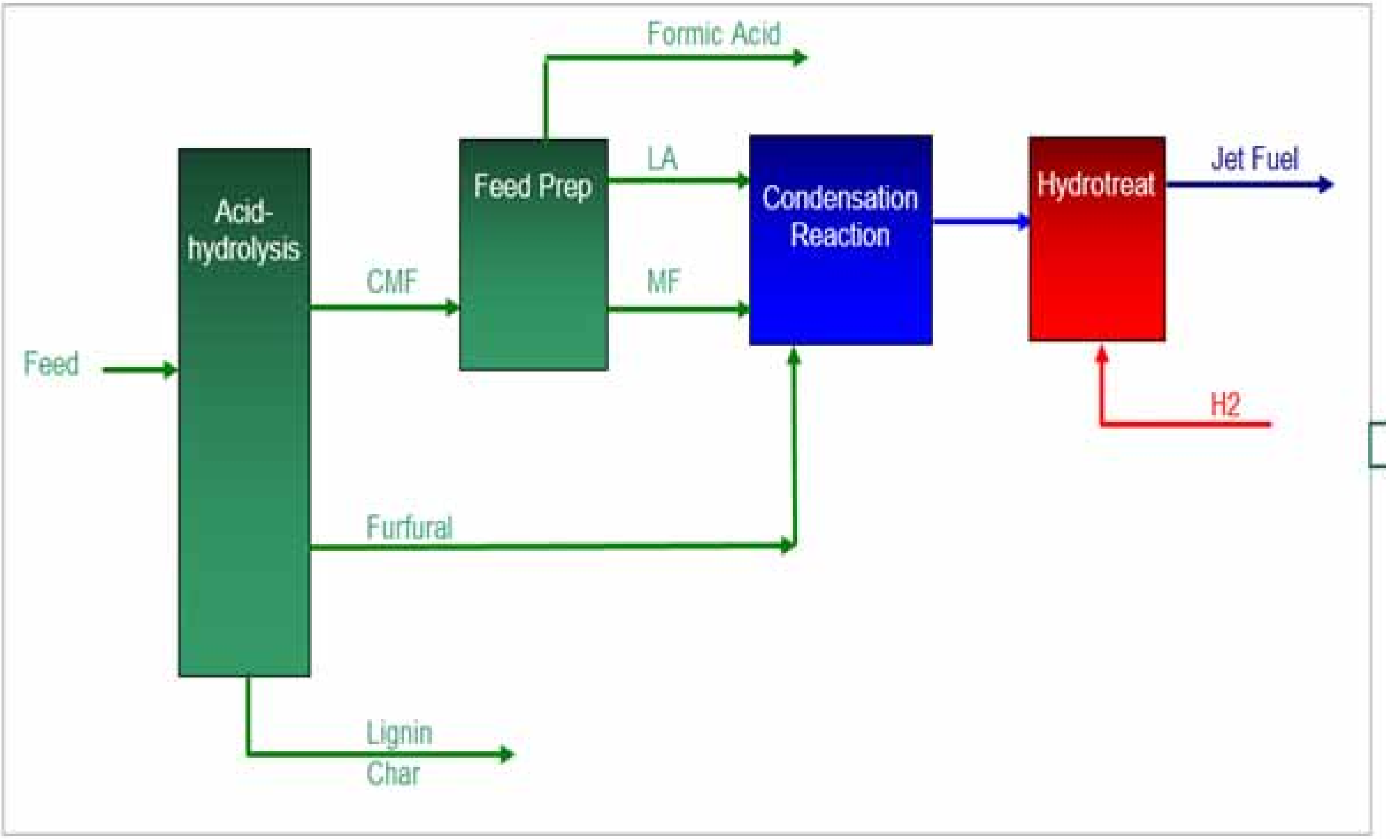
- *Use accepted Front End Loading (FEL) project management procedures to manage project.*
- *Focus on safety especially during BP-2 activities.*
- *Reduce CapEx by re-using existing equipment and facilities.*
- *Reduce OpEx by sharing or contracting with existing/trained labor.*
- *Maximize in-kind cost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

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 and identified most promising pathway.*
  - *Purdue scaled up both condensation feed generation and condensation reactions.*
- *Hydrotreating -*
  - *Battelle ran small scale hydrotreating with Purdue supplied feedstock.*
  - *Mixed results but accomplished primary objective of complete deoxygenation to jet fuel 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:*



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

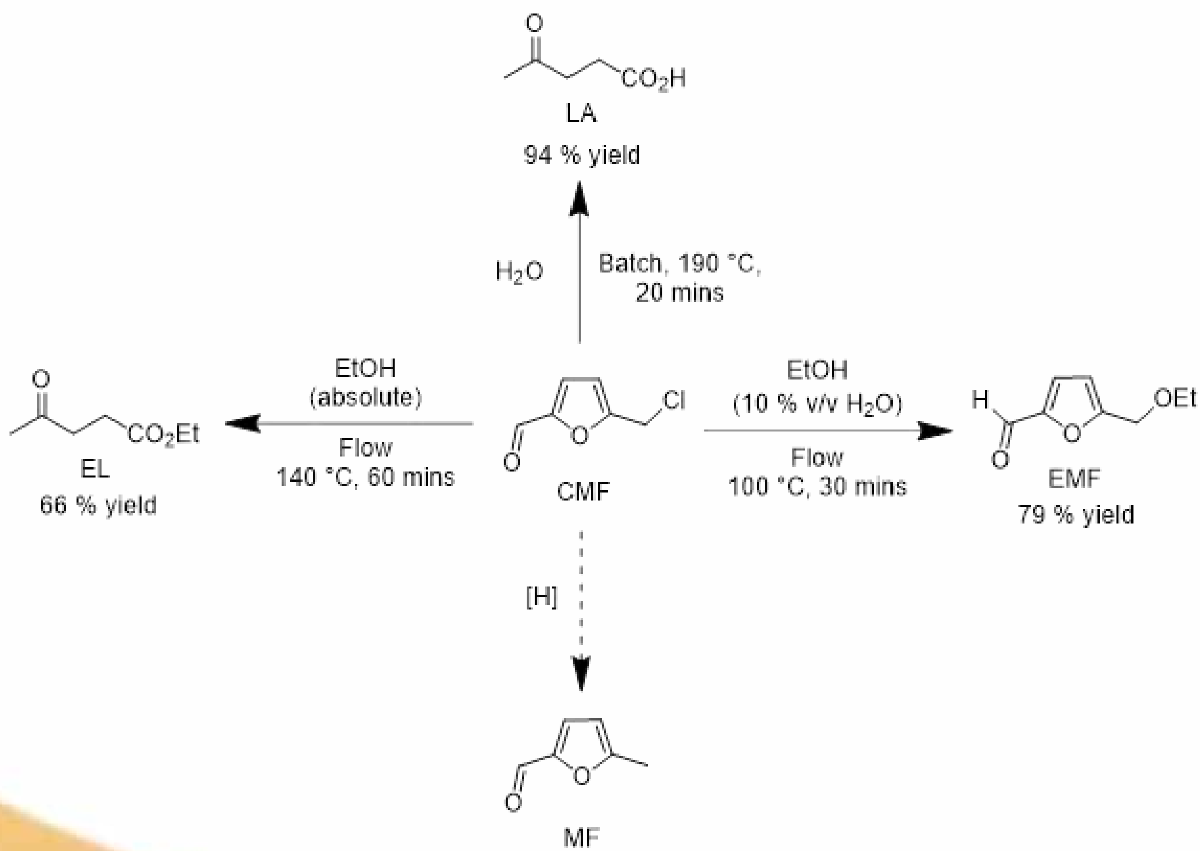
- *Acid Hydrolysis Data:*

Untreated cornstover produced a maximum of 77% theoretical yield of CMF. Increasing the loading to 20% decreased the CMF yield to 63%.

<table>
<tr><th rowspan="12">Biomass
Cornstover</th><th>Expt No.</th><th>Biomass</th><th>Loading (%)</th><th>Solvent</th><th>No. of solvent extractions</th><th>Time (h)</th><th>HCl</th><th>CMF (% mass of biomass)</th><th>CMF (% theoretical yield %)</th></tr>
<tr><td>LP-2-15</td><td rowspan="8">Milled</td><td rowspan="2">2.5</td><td rowspan="6">DCE</td><td>6</td><td>5</td><td rowspan="9">37%</td><td>27.1</td><td>76.9</td></tr>
<tr><td>LP-2-22</td><td rowspan="7">4</td><td rowspan="7">3</td><td>26.2</td><td>74.4</td></tr>
<tr><td>LP-2-25</td><td>5</td><td>26.4</td><td>74.9</td></tr>
<tr><td>LP-2-28</td><td>10</td><td>22.7</td><td>64.5</td></tr>
<tr><td>LP-2-34</td><td>15</td><td>19.1</td><td>54.3</td></tr>
<tr><td>LP-2-37</td><td>20</td><td>22.2</td><td>62.9</td></tr>
<tr><td>LP-2-50</td><td rowspan="2">2.5</td><td>25% DCE: 75% Toluene</td><td>14.3</td><td>40.7</td></tr>
<tr><td>LP-2-53</td><td>Toluene</td><td>13.2</td><td>37.4</td></tr>
<tr><td>25</td><td rowspan="3">GFR 8 (210° C) Residue</td><td rowspan="3">1</td><td rowspan="3">Toluene</td><td rowspan="3">1</td><td rowspan="3">1</td><td>23.1</td><td>42.6</td></tr>
<tr><td>28</td><td rowspan="2">20%</td><td>0</td><td>0</td></tr>
<tr><td>29</td><td>0</td><td>0</td></tr>
</table>

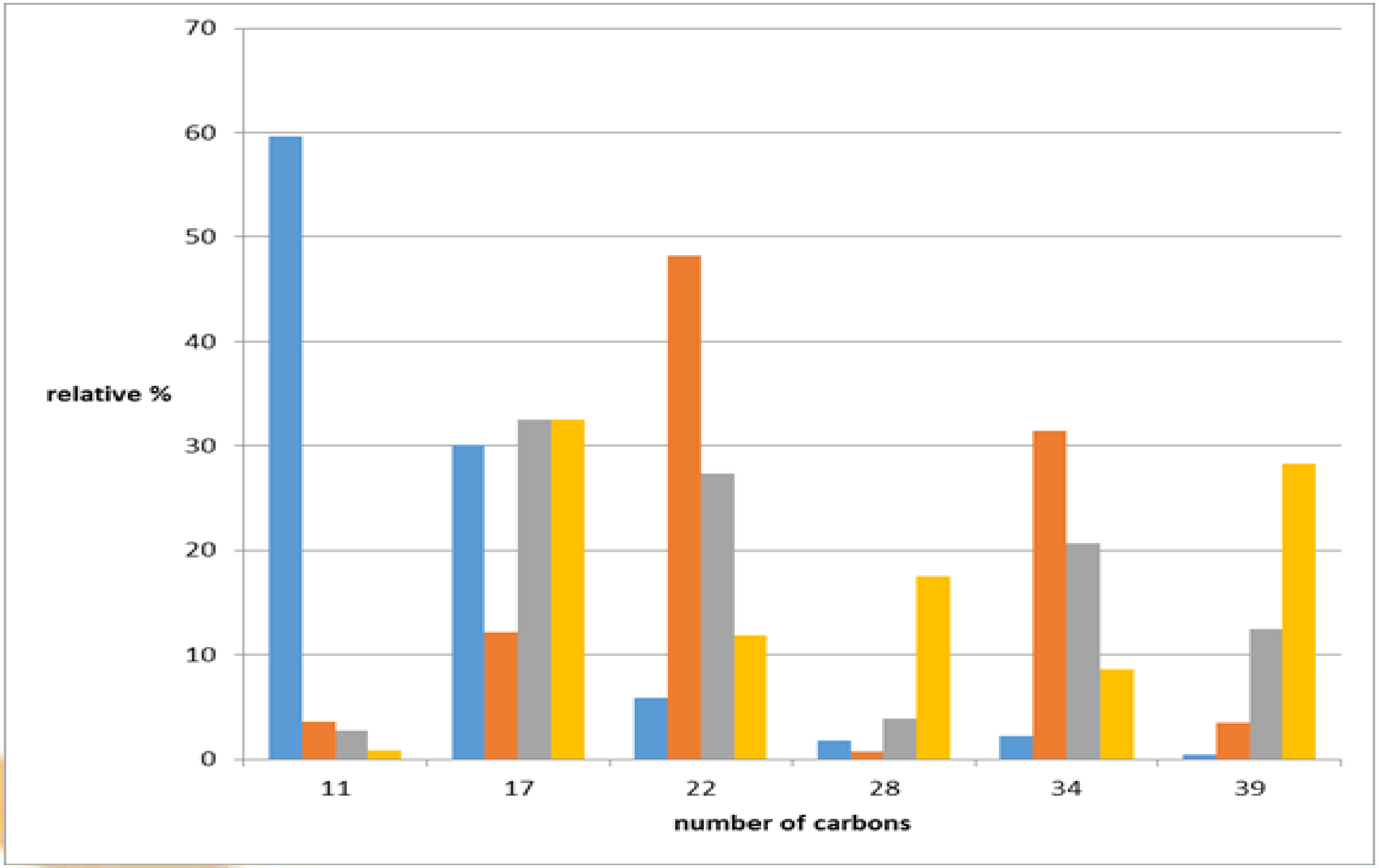
3 – Technical Accomplishments/ Progress/Results (cont'd)

- *Feed Prep Data:*



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

- *Condensation Data:*



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*

- *Provides viable, low cost pathway from cellulosic biomass to drop-in, hydrocarbon jet fuel and diesel.*

5 – Future Work

- *BP-1B will start in April 2015, 4-6 months to complete FEL engineering for the pilot plant.*
- *After a GO decision at the end of BP-1B move into BP-2.*
- *Final budget period, BP-2:*
  - *Detailed design of pilot*
  - *Procurement and construction of pilot*
  - *Startup and operation*
  - *Investigation of multiple feedstocks, recycles, recoveries, etc.*

Summary

- Early stage project that is on track to meet project deliverables and milestones.
- Successfully completed BP-1A.
- 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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