2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

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

11.2.2.4 Techno-Economic Analysis of Innovative Technology Concepts

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Analysis & Sustainability

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Goal Statement

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- Provide analytical basis for BETO's Research and Development Thrusts:
  - Initial technical and economic screening of conversion technologies utilizing common methodologies for economic evaluation
  - Identify areas of largest potential for cost reductions for guiding R&D
- Support BETO's Goals (from the MYPP):
  - "By 2014, select, complete techno-economic modeling, and set goals and targets for at least [four] hydrocarbon pathways…"
  - By "ensuring high-quality, consistent, reproducible, peer-reviewed analyses"
  - "Developing analytical tools, models, methods, and datasets to advance the understanding of bioenergy and its related impacts"
  - "Conveying the results of analytical activities to a wide audience, including DOE management, Congress, the White House, industry, and the general public"

Quad Chart Overview

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Timeline

- October 1, 2011
- Continuing through FY15
- FY12 100% complete

Budget

- Funding for FY11 (0)
- Funding for FY12 (200k)
- Funding for FY13 (200k)
- 2 years funding at an average of 200k/year

Barriers

- **At-A:** Lack of comparable, transparent and reproducible data
- **Im-F:** Cost of production
- **It-E:** Engineering modeling tools

Partners

- PNNL
- ISU
- Project management – ISU subcontracted to PNNL

Project Overview

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- **History**: new start for FY12
- **Context**:
  - BETO's portfolio expanded to include hydrocarbon fuels
  - Need for quick preliminary analysis of candidate pathways routes
- **Objective:** Support the BETO analysis for enabling the production of advanced biofuels and meeting 2017 & 2022 targets
  - Rapid screening economics of four-to-six pathways each year
  - Leverage open literature and experimental data from both institutes

Approach

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- **TECHNICAL APPROACH**
- Quick screening, then detailed analysis
- Iterative process
- Sensitivity analysis to understand variance & significant impact areas
- Leverage University and National Lab expertise

TEA, screening LCA

Input from researchers, clients, literature

Process Modeling

GOAL Guide Research

NEW PROCESS, FUEL, PRODUCT

Excel, Aspen & Chemcad quick analysis for Go/No Go

MANAGEMENT APPROACH

- Develop project management plans
  - Statement of work with relation to DOE goals
  - Quarterly milestones minimize project slippage
  - Frequent project communications – data exchanges for review
  - Monthly lab and HQ calls
  - Quarterly formal reporting to HQ & reviews

Milestones/Metrics and Progress

Title/Description	Due Date	Completed
Finalize common methodologies and select processes for comparison to $3/gal target	Dec-11	✓
Complete first high level TEA and compare to $3/gal target	Mar-12	✓
Complete 2nd and 3rd high level TEA and compare to $3/gal target	Jun-12	✓
Finalize all TEAs and compare to $3/gal target	Sep -12	✓
Submit final report	Sep-12	✓
Review pathways choices with BETO	Dec-12	✓
Complete 1st high level TEA	Mar-13	✓
Complete 2nd and 3rd high level TEAs	Jun-13	In progress
Finalize all TEAs and submit final report	Sep-13	In progress

FY12

- Completed 4 high level screening models, two of which were leveraged for BETO's Pathway Selection Working Group to prioritize pathways for future research
- Summarized in milestone report to HQ

FY13 obtained HQ approval for work on 4 new pathways – results will be used to assist the Gasification technology area to assess possible future research areas

Technical Accomplishments / Progress / Results

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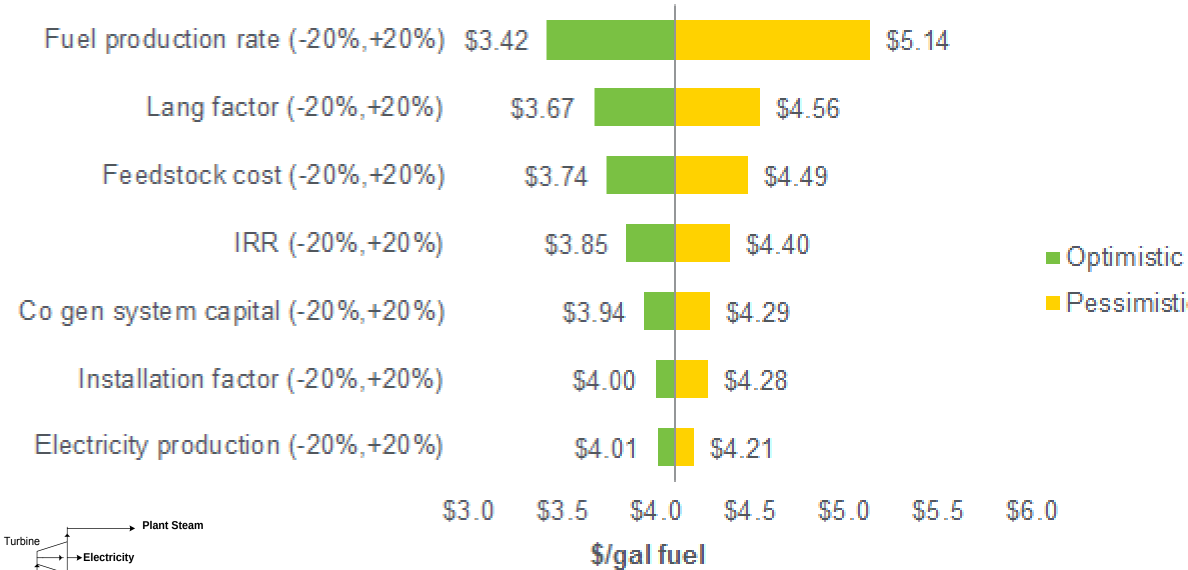
Chose conservative assumptions regarding stream factor, feedstock cost and Lang to reflect preliminary nature of the analysis

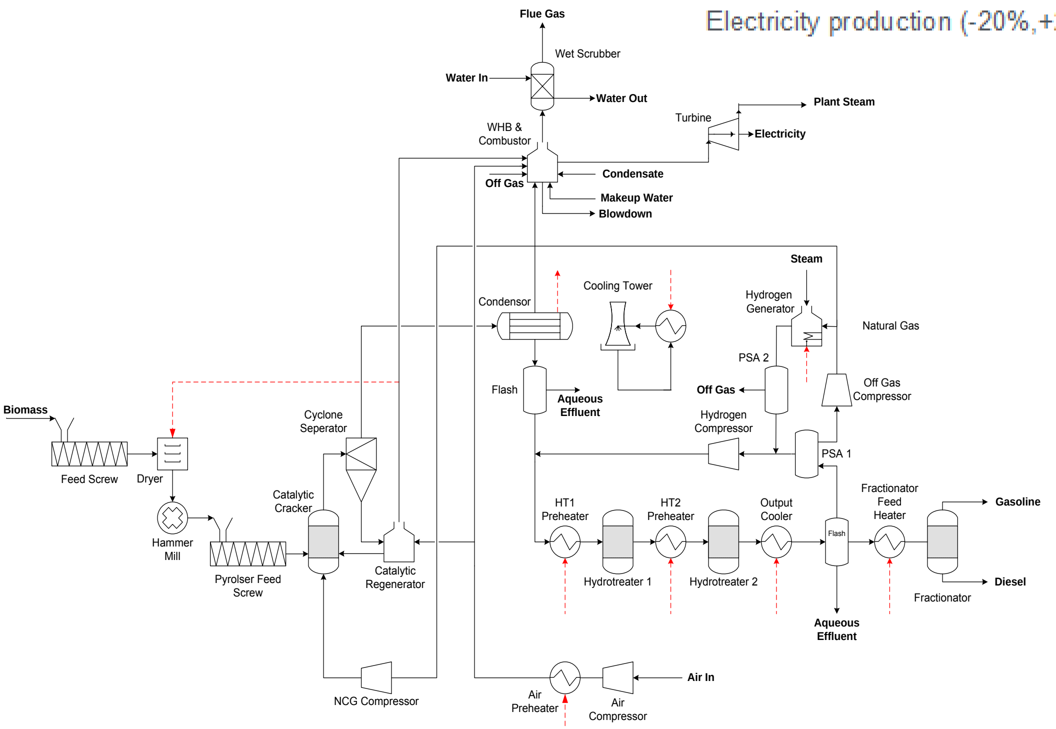
Assumptions used in the Analysis			
Cost year	$US 2011	Loan interest	8%
Feedstock	96 $/dry US ton		
Stream factor	90%	Internal rate of return (after tax)	10%
Plant Life	30 years	Income tax rate	39%
Construction	2.5 years	Lang factor	5.46
Startup time	0.5 years	Working capital	15% of FCI
MACRS Depreciation	General plant: 7 years Steam plant: 20 years	Property tax and Insurance	2% of FCI
Equity	40%	Maintenance	2% of FCI
Loan term	10 years	Gen & Admin ovhd	95% of labor

Technical Accomplishments / Progress / Results

FY12 Analysis

***Insitu* Catalytic Pyrolysis: catalyzed fast pyrolysis in a single vessel; separate finishing hydrotreating**





Challenges:

- Retain as much carbon in intermediate oil as possible
- Catalyst development
- Demonstrate lower cost fuel finishing (such as reduced hydrotreating)

Technical Accomplishments / Progress / Results

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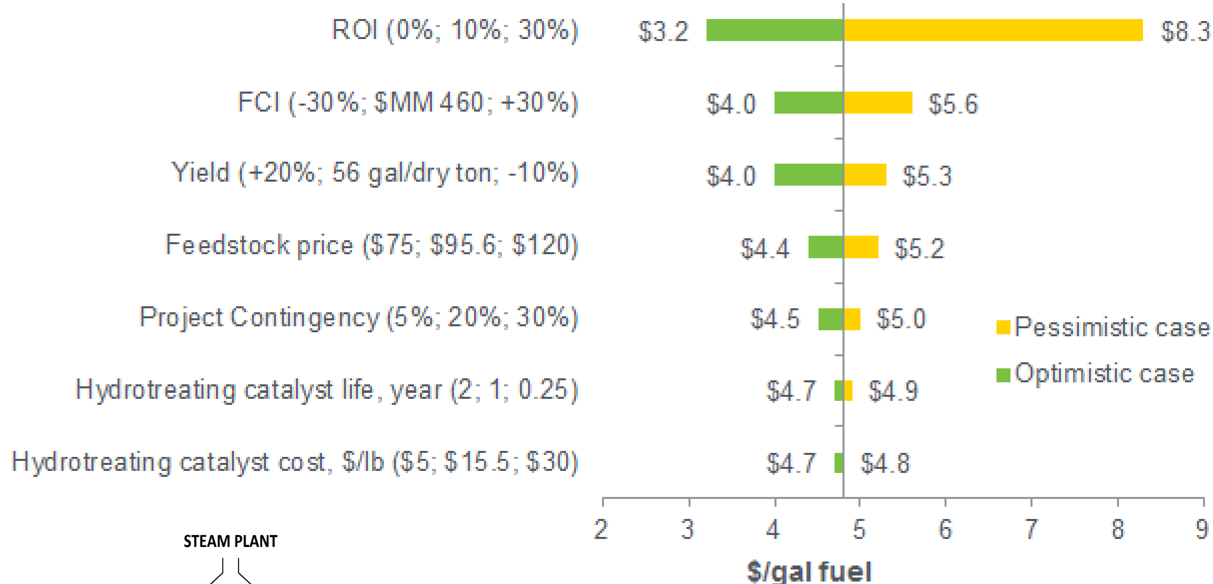
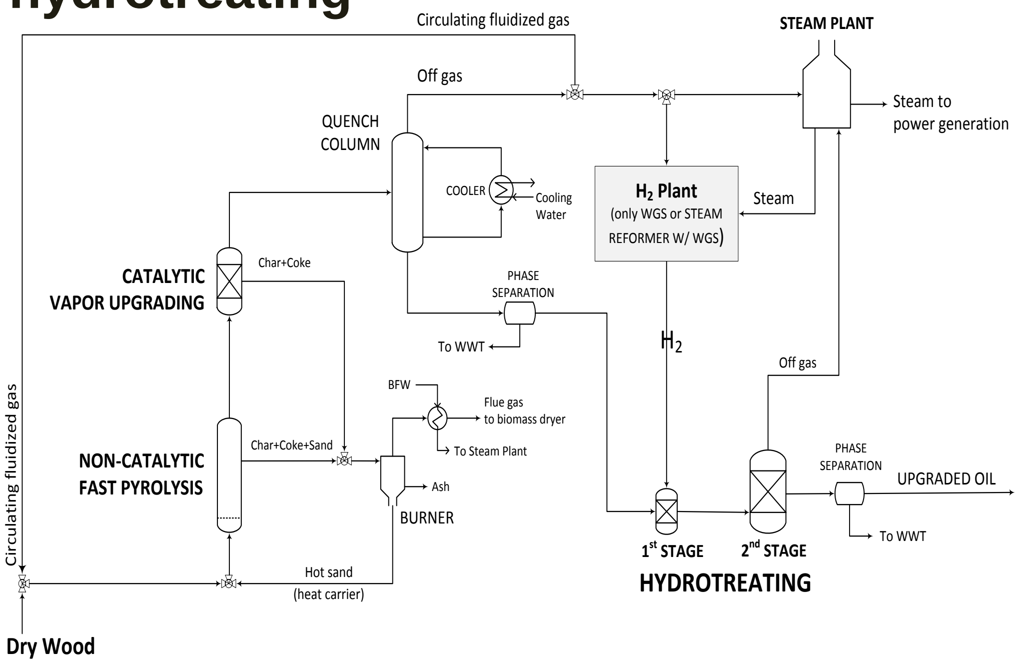
FY12 Analysis

***Exsitu* Catalytic Pyrolysis: fast pyrolysis with vapor phase upgrading in a separate vessel, and separate finishing hydrotreating**





FRACTIONATION
UPGRADED OIL
GASOLINE
H2
GASOLINE
DIESEL
HYDROCRACKING

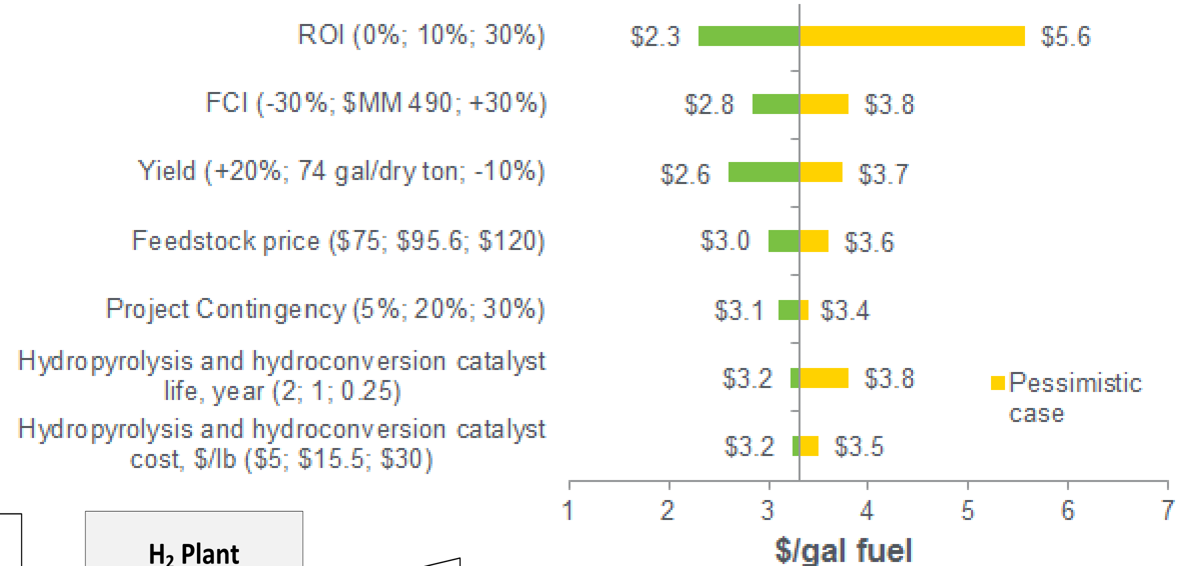
Challenges:

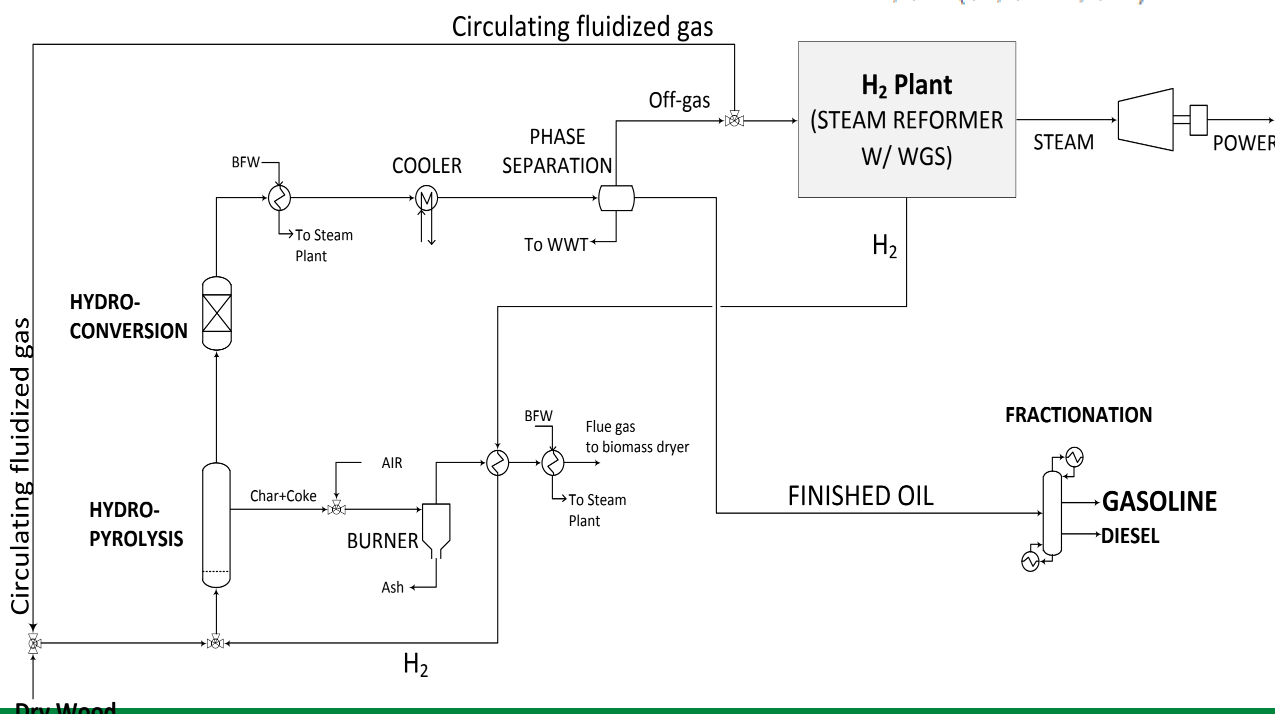
- Retain as much carbon in intermediate oil as possible
- Catalyst development
- Demonstrate lower cost fuel finishing (such as reduced hydrotreating)

Technical Accomplishments / Progress / Results

<u>FY12 Analysis</u>

Hydropyrolysis: catalyzed fast pyrolysis in the presence of hydrogen with separate vapor phase finishing hydrotreating





Challenges:

- Limited published data
- Catalyst development

2 – Technical Accomplishments / Progress / Results (cont.)

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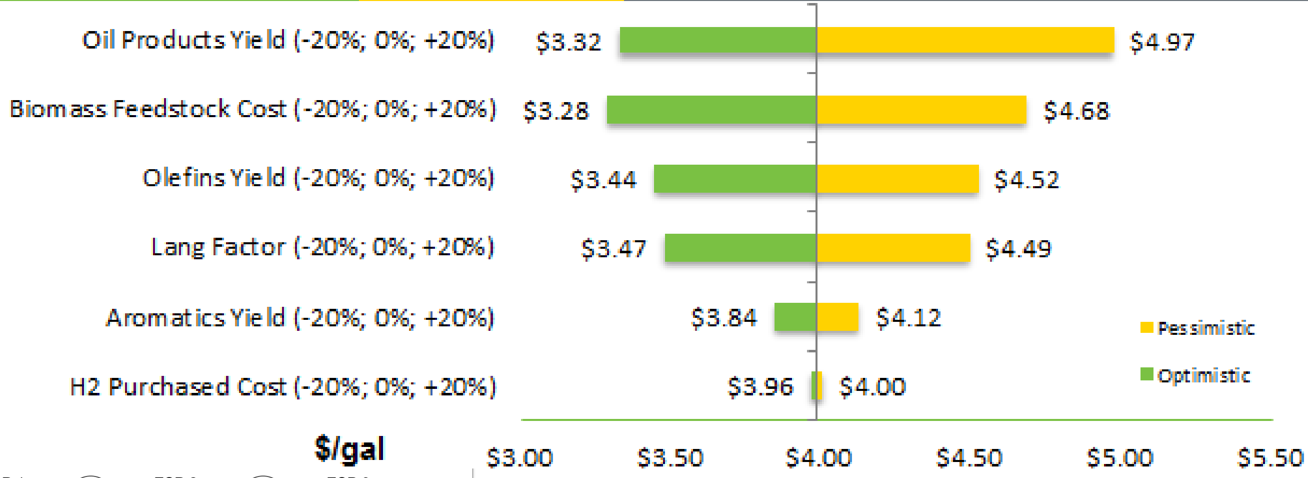
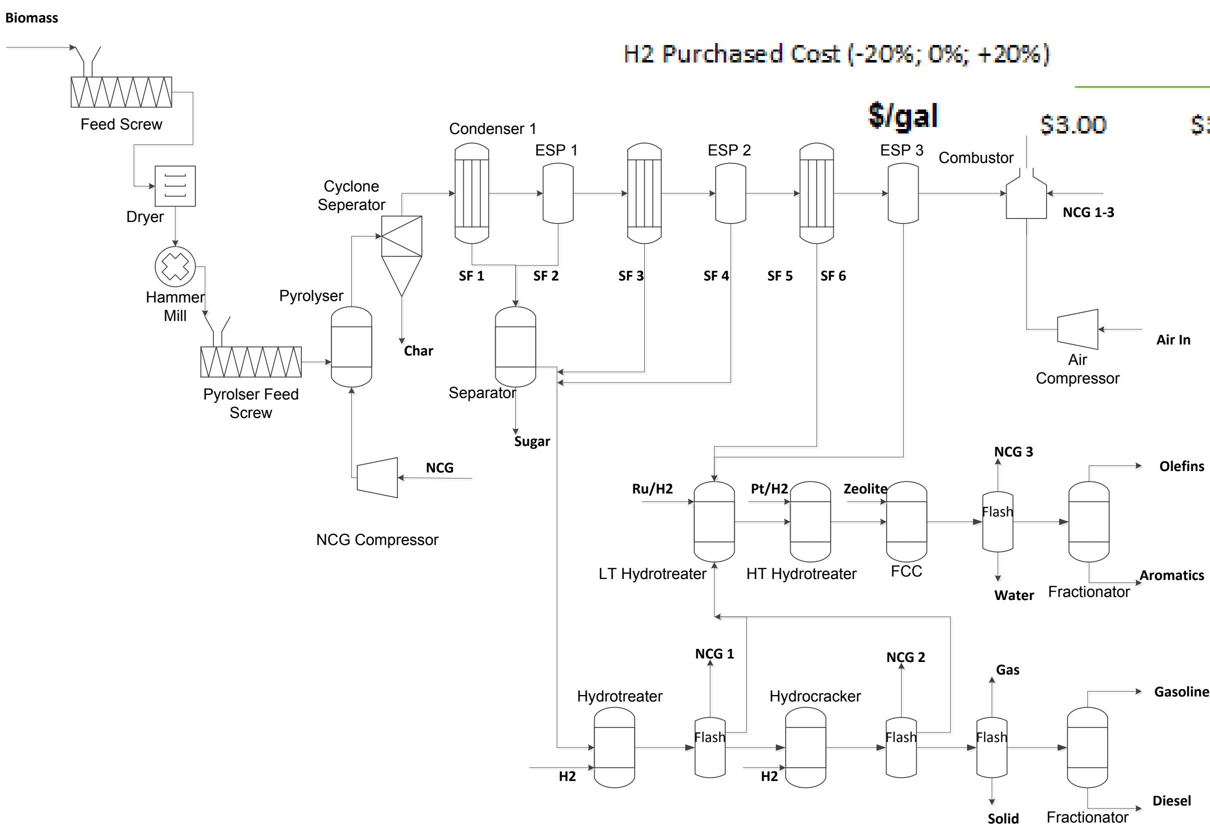
FY12 Analysis

Fuels and Products from the fractionation of Fast Pyrolysis





Challenges:

- Need product quality data
- Catalyst development

Technical Accomplishments Key Outcomes

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	Uncatalyzed Fast Pyrolysis and liquid phase upgrading	Case 1: In-situ vapor phase catalytic pyrolysis	Case 2: Ex-situ vapor phase catalytic pyrolysis
Bio-oil Production	Single reactor	Single reactor	Two reactors
Intermediate Bio-oil quality	~50% oxygen plus associated water, More difficult to upgrade	Lower oxygen content in product, easier to upgrade	Lower oxygen content, easier to upgrade. Two reactors allow more control over gas/liquid/solid, possible lower catalyst inventory than in-situ
Upgrading to hydrocarbon Capital	At least two upgrading reactors in series Reactors see 100% of the produced water, plus feedstock moisture	Potentially a single upgrading reactor Reactors see small fraction of produced water	Potentially a single upgrading reactor Reactors see small fraction of produced water
Upgrading catalyst life	Still short	Potentially longer	Potentially longer
Waste water treatment	No wastewater from fast pyrolysis. Wastewater from upgrading to hydrocarbons very low in organics	Could have high concentration of dissolved organics	Could have high concentration of dissolved organics
Hydrocarbon Yield	Highest so far	Lower than conventional pyrolysis and upgrading so far	Lower than conventional pyrolysis and upgrading so far

Technical Accomplishments / Progress / Results

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FY13 Analysis to date:

- ISU lead: catalytic pyrolysis of microalgae
- PNNL lead: gasification with syngas fermentation and upgrading to hydrocarbons

Relevance

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The project directly supports the Bioenergy Technologies Office's development of pathways and technical targets in the 2017 through 2022 timeframes

Helps DOE and industry understand critical issues related to hydrocarbon production as they relate to targets for 2017 and 2022

This research enables the BETO's strategic goal *"to develop technologies for converting feedstocks into cost-competitive liquid transportation fuels, as well as bioproducts and biopower"*

Critical Success Factors

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- Identification of promising new pathways and data gaps
- Ensuring consistent and appropriate assumptions across each analysis
  - Frequent telecons with ISU collaborators
  - PNNL and ISU cross review of all work
  - Quarterly formal reporting to HQ

- Availability of key research and cost information form an important challenge
  - Engage researchers at PNNL and ISU
  - Data sharing between PNNL and ISU

- What do the numbers mean?
- How to put context around pathways that are at different TRLs?
- How do we model and dissemenate when there is IP that needs to be captured?
- How do we evaluate emerging technologies (as opposed to pathways) and provide sufficient detail to BETO if these should be looked at first?

Future Work

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ML, DL or Go/No Go	Description	FY13 Q3	FY13 Q4	FY13 4 Q4	FY14 Q1
B.ML.3	2nd & 3rd high level TEAs completed	■			
B.ML.4	Complete at least one additional TEA		■		
B.ML.5	Go-No Go: Project continuation decided			■	
C.ML.1	If continuation approved, seek approval for selected routes				■

FY13 screening cases for potential future pathways

- Solvent liquefaction: solvent-based direct liquefaction in a reactor operating at high pressure and moderate temperature. Feedstock could be either microalgae or cellulosic biomass
- Enzymatic sugar to hydrocarbon via biochemical or aqueous phase processing
- Pyrolytic sugar to hydrocarbon via biochemical or aqueous phase processing
- Gasification and mixed oxygenate upgrading

Successful FY13 outcome will be identification of potentially economic pathways, gaps and research needs particularly for the gasification based routes

Summary

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Approach: Iterative process, ISU and PNNL share and review results

Technical accomplishments

- FY12 – 4 pathways completed
- FY13 – began 4 new pathways
- Identify gaps and research opportunities

Relevance:

- This project is in direct alignment with BETO's mission and goals for reducing dependence on petroleum and for achieving cost parity with conventional transportation fuels

Critical Success factors and challenges

- Leverage results for more detailed pathway analysis

Future Work: Screen 4-6 new pathways each year

Technology transfer: Formal report to HQ

Acknowledgements

Bioenergy Technologies Office – Zia Haq, Alicia Lindauer, Kristen Johnson

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ISU Team – Chamila Thilakaratne, Li Yihua, Tristan Brown, Robert Brown

Additional Slides

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Responses to Previous Reviewers' Comments

- This project was a new start in FY12 and hence has not been previously reviewed

Publications, Presentations, and Commercialization

- Planned Publications (Iowa State University)
  - Thilakaratne *et al*. “Mild Catalytic Pyrolysis of Biomass for Production of Transportation Fuels: A Techno-economic Analysis”
  - Li *et al*. “Techno-economic Analysis of Biochemicals and Liquid Fuels via Fast Pyrolysis Fractionation”
  - Ou *et al*. “Techno-economic Analysis of the Production of Hydrocarbons from Pyrolytic Sugars”
  - Thilakaratne *et al*. “Techno-Economic Comparison of Direct Liquefaction Pathways for Producing Drop-In Biofuels from Microalgae Remnants”