2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

BioChemCat

Date: April 21, 2013
Technology Area Review: Gasification
Principal Investigator: Birgitte K. Ahring, PhD
Organization: Washington State University

A partnership between the Port of Benton, WSU, CleanVantage, LLC and PNNL

PORT OF BENTON

WASHINGTON STATE UNIVERSITY TRI-CITIES
World Class. Face to Face.

CleanVantage

Pacific Northwest NATIONAL LABORATORY

Role of Partners

Project holder, Delivery of biomass feedstocks, Public Education & Outreach

IP Holder, Pretreatment, Fermentation, Low/Moderate Severity Lignin Conversion

Research Lead, Pilot plant operations, Analytical Testing & Public Education & Outreach

Sub-contractor, Catalytic upgrading into fuels

Goal Statement

- **To develop an integrated thermochemical/biochemical conversion process that can efficiently and cost-effectively process agricultural residues and other biomass wastes into infrastructure compatible biofuels and bioproducts.**

Quad Chart Overview

Timeline

- Project Start Date: 30 Oct. 2010
- Project End Date: 31 Mar. 2014
- Percent Complete: 66.72%

Barriers

- Biomass recalcitrance
- Pretreatment costs
- Biochemical/thermochemical process integration

Budget

Federal FY	$ Spent ($ Bud.)	Cost Share
2012	$501,147	$50,397
2013	$318,431	$388,699
2014	$131,922	$53,898
Ave. Ann. Funding	$317,167	$164,331

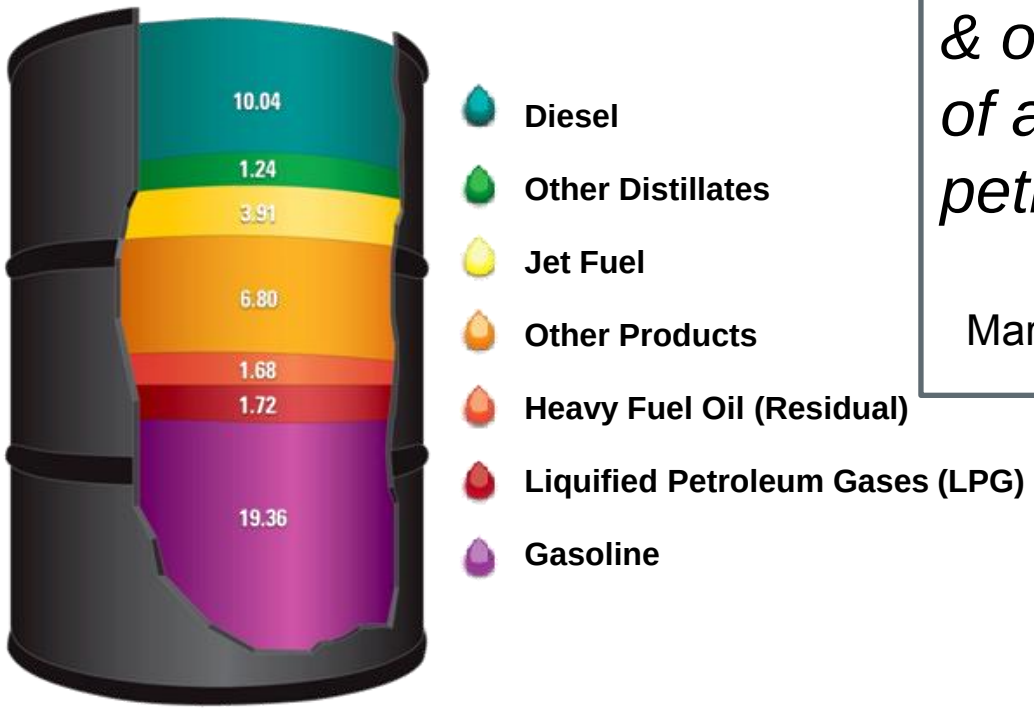
Years Project Funded: 3

Partners

- Port of Benton
- CleanVantage, LLC
- Pacific Northwest National Laboratory

Current Uses of Petroleum

Products Made from a Barrel of Crude Oil (Gallons)
(2009)

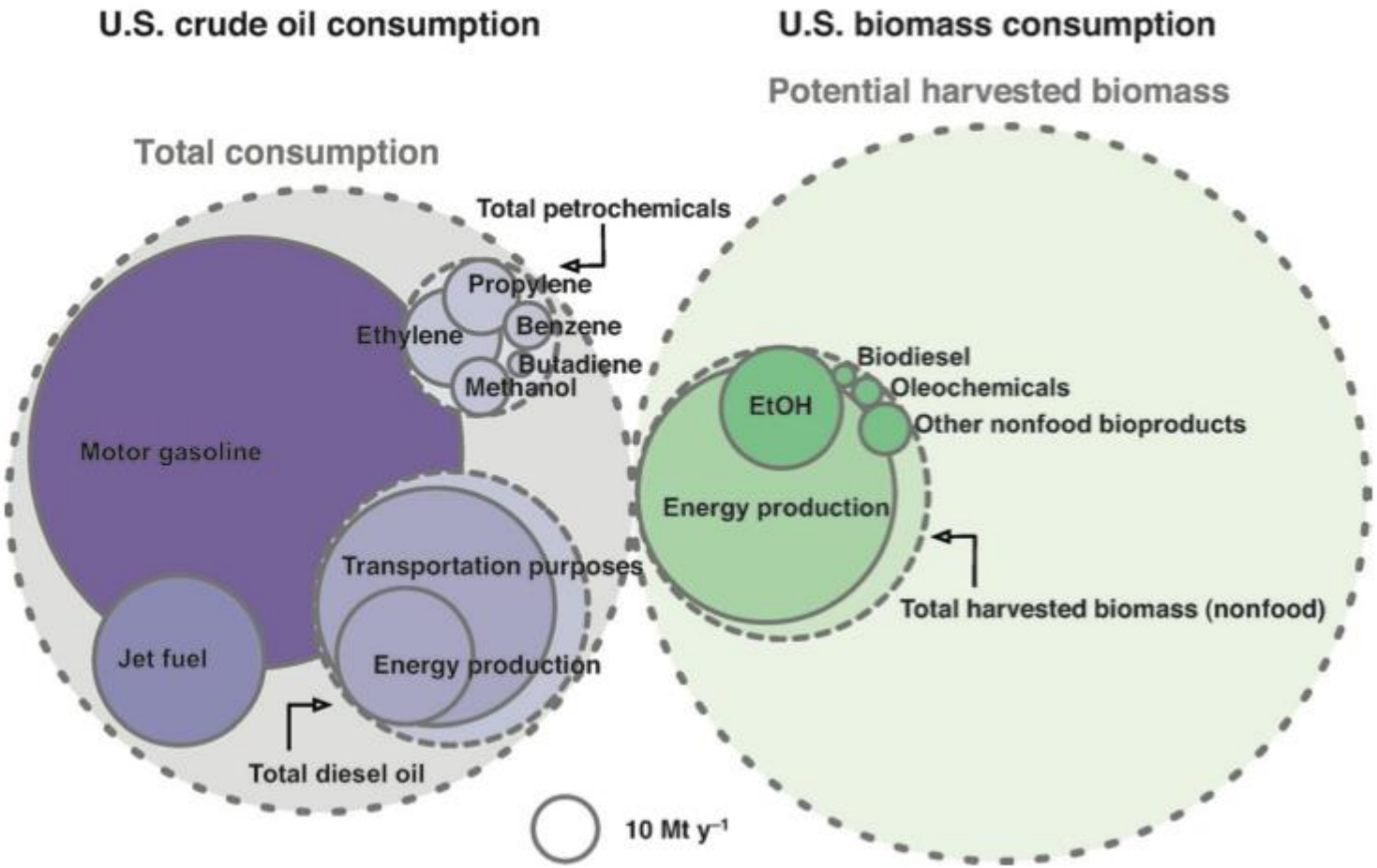


Feedstocks like naphtha, pen-hex, BTX, light paraffins & olefins help form the basis of a ~$375 billion petrochemical industry.

Marshall *New Scientist*, **2007**, 28-31

Source: Energy Information Administration, "Oil: Crude Oil and Petroleum Products Explained" and AEO2009, Updated February 2010, Reference Case.

Value from Fuels & Products



Full Biomass Utilization & Feedstock Flexibility

Integrated biorefinery process concept maximizes the utilization of the biomass resource (i.e., converting the biomass available into a number of high energy products). We call it the:

"THE CARBON SLAUGHTERHOUSE"

Wheat Straw

Grape Pommace

Corn Stover

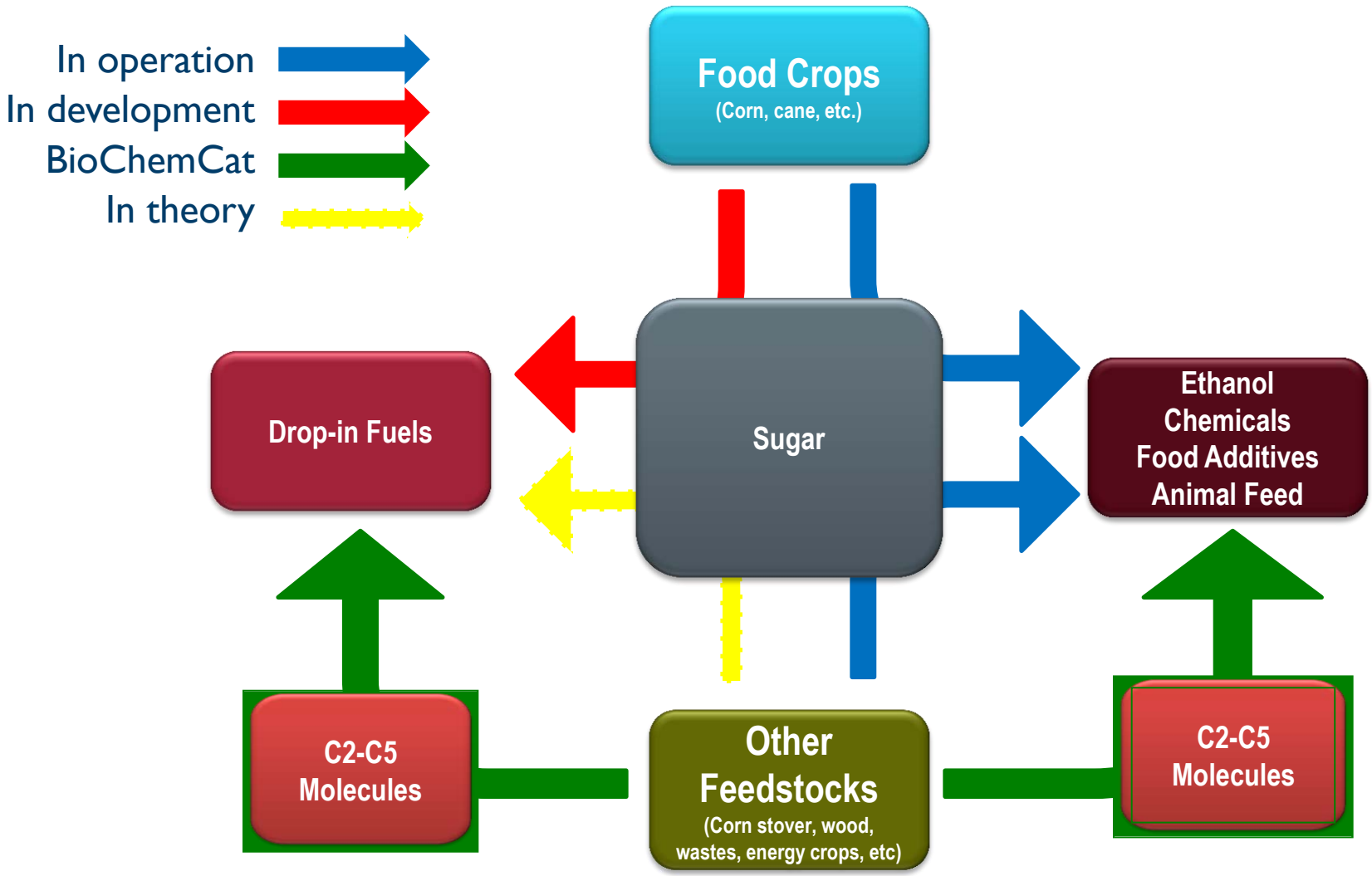
Hop Wastes

Paper and Food Waste

Yard Wastes

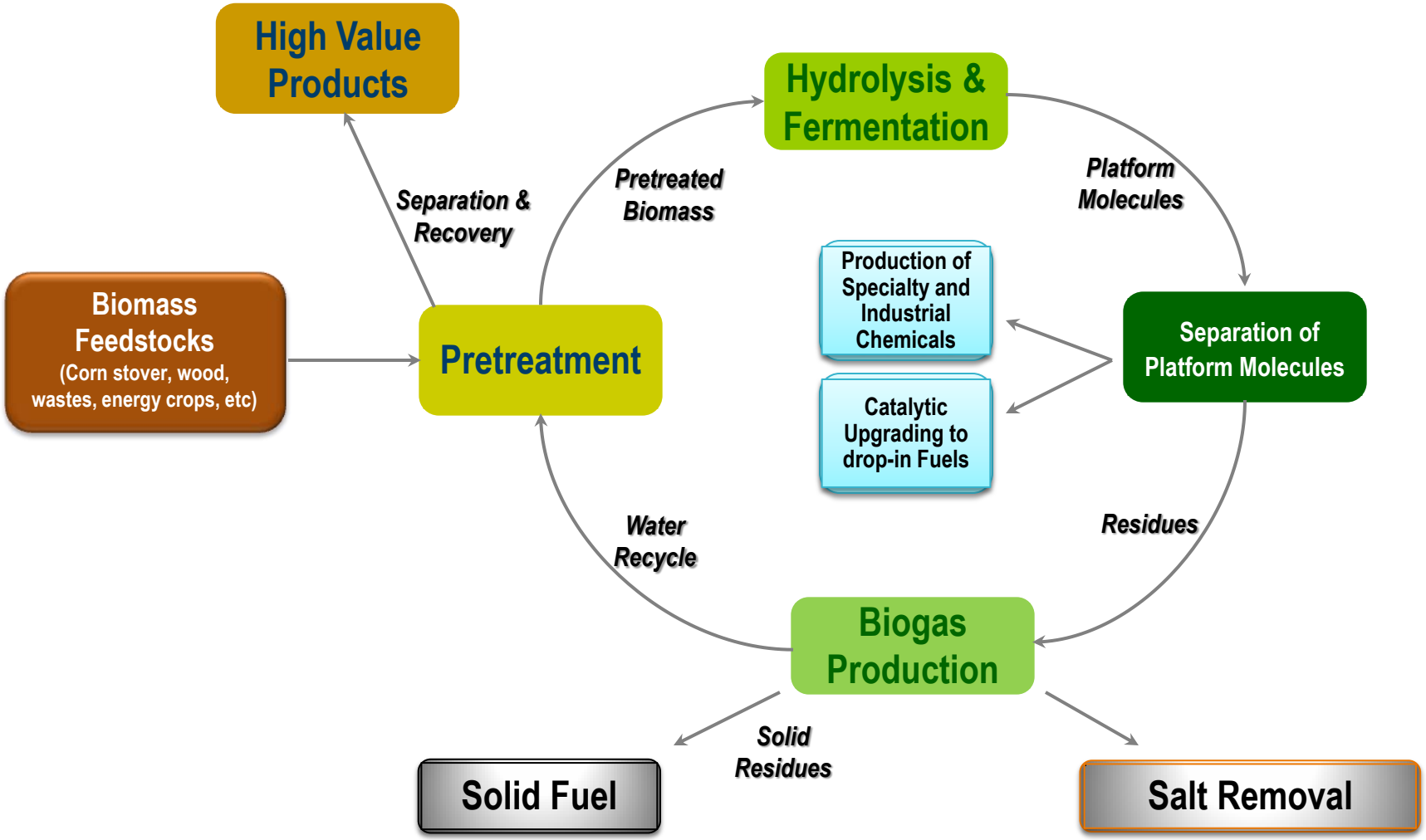
The Integrated Biorefinery concept can use many different types of biomass materials

Today's Biorefineries & BioChemCat

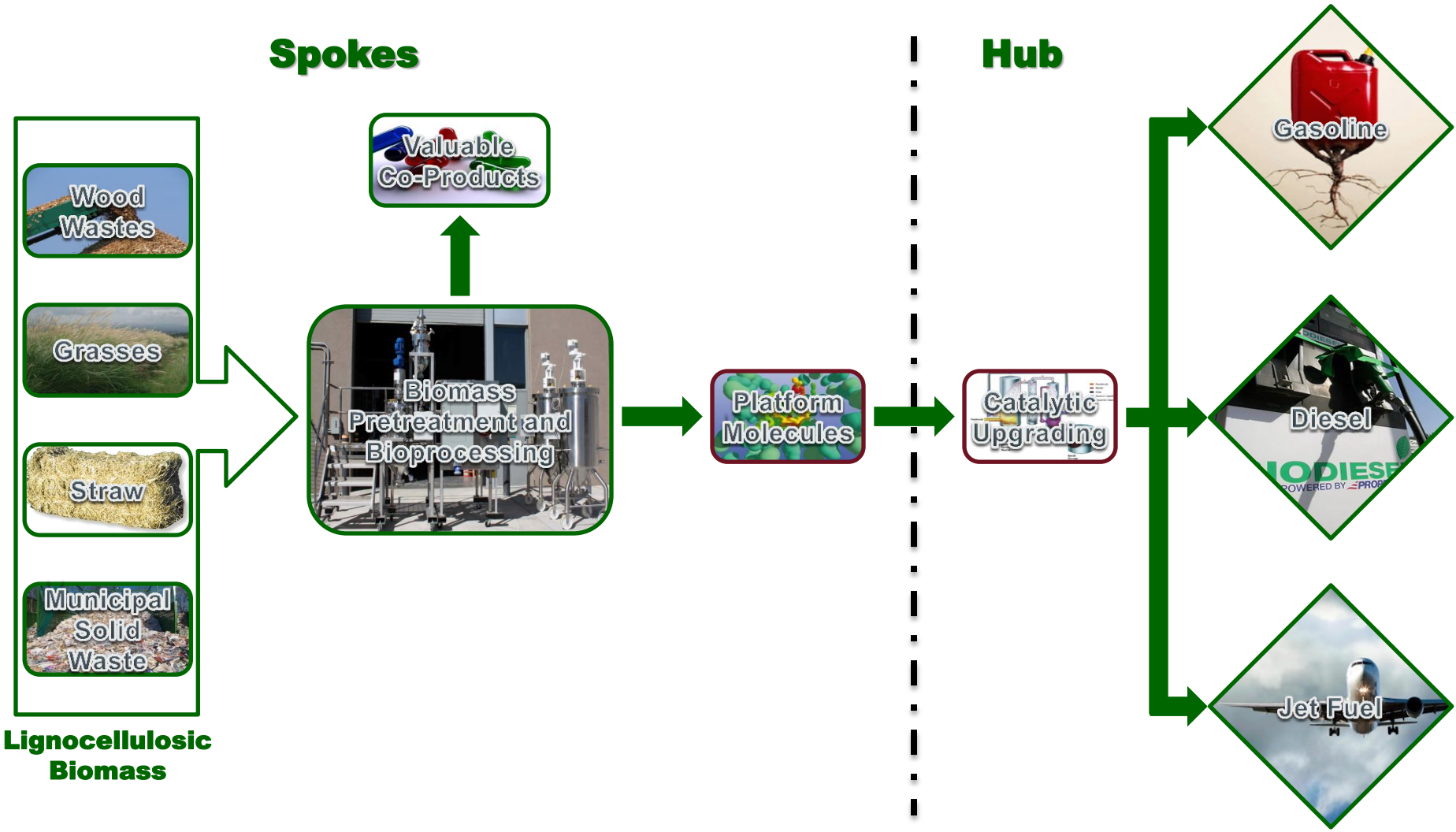


The BioChemCat Process

A hydrolysate platform

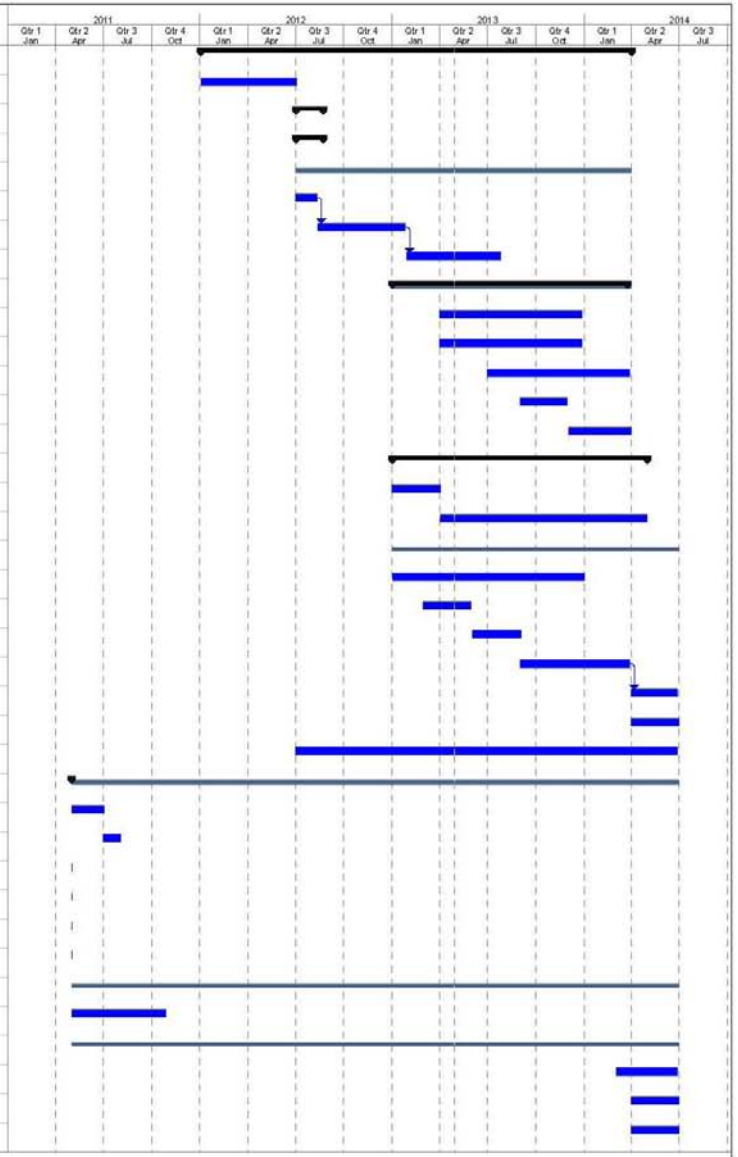


Non-enzymatic Hydrolysate Platform BioChemCat Process



Project Schedule

ID	WBS	Task Name	Duration	Start
1	1	**Construct BioChemCat Conversion System**	**585 days**	**1/3/12**
2	1.1	**Construct BioChemCat Conversion System**	**130 days**	**1/3/12**
3	1.2	**Startup and Commissioning**	**38 days**	**7/2/12**
4	1.2.1	**Startup Testing**	**38 days**	**7/2/12**
15	1.3	Operate Pilot Facility		
16	1.3.1	Establish Platform Molecule Fermentation Seed Culture	30 days	7/2/12
17	1.3.2	Perform Operational Preliminary Testing	120 days	8/13/12
18	1.3.3	Upscale Pretreatment to 200 liters/hr	129 days	1/28/13
19	1.3.4	Platform Molecule Fermentation in 300 L/hr Scale Using Different Feedstocks (grape pommace, hog fuel, straw, etc.)	320 days	1/1/13
23	1.3.5	Membrane Separation of Platform Molecules	195 days	4/1/13
24	1.3.6	Production of Platform Molecules for PNNL	195 days	4/1/13
25	1.3.7	Platform Molecules Upgrading via Catalysis	195 days	7/1/13
26	1.3.8	Lignin Separation and Additional Solubilization	64 days	9/2/13
27	1.3.9	Platform Molecule Production from Lignin	96 days	12/2/13
20	2	**Techno-economic Assessment**	**347 days**	**1/1/13**
29	2.1	Initial Techno-economic Assessment	66 days	1/1/13
30	2.2	Revised Techno-economic Assessment	282 days	4/2/13
31	3	**Platform Molecule System Operational Research and Optimization**		
32	3.1	Collect Operational Data on Plant Unit Processes	260 days	1/2/13
33	3.2	Assess and Compile Data	64 days	3/1/13
34	3.3	Modify Operations Models	66 days	6/3/13
35	3.4	Validate Operating Assumptions	150 days	9/2/13
36	3.5	Prepare and Revise Proforma Operating Spreadsheets	65 days	3/31/14
37	3.6	Update Commercialization Plan	65 days	4/1/14
38	4	**Provide Educational and Business Development Outreach**	**520 days**	**7/2/12**
39	5	**Project Management**		
40	5.1	Project Planning & Control	45 days	5/2/11
41	5.2	Project Objectives	23 days	7/1/11
42	5.3	Implement Quality Assurance/Quality Control Activities	1 day	5/2/11
43	5.4	Monitor Subcontract Activities	1 day	5/2/11
44	5.5	Manage and Coordinate Regulatory Agency Interactions	1 day	5/2/11
45	5.6	Manage and Coordinate Public Communications and Interactions	1 day	5/2/11
46	5.7	**Project Organization and Management**		
47	5.7.1	Organization Plan	129 days	5/2/11
48	5.7.2	**US DOE Contract Submittals**		
100	5.7.3	Updated Proformas	85 days	3/3/14
101	5.7.4	Final Technical Report	65 days	4/1/14
102	5.7.5	Final Intellectual Property (IP) Report	65 days	4/1/14



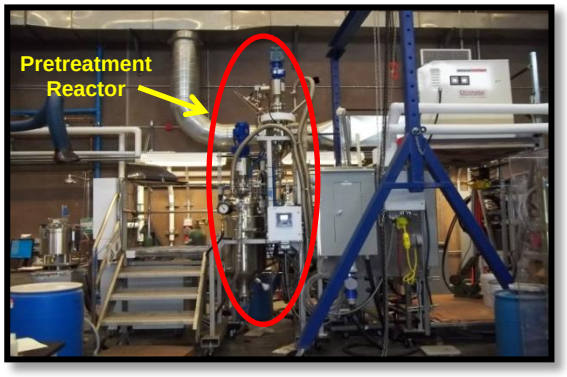
Project: WBS Northwest Integrated Bio

Task · Split · Milestone · Summary · Project Summary · External Tasks · External Milestone · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only · Progress · Deadline

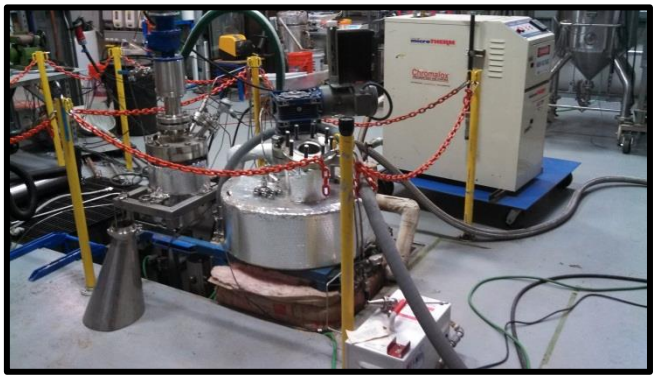
Project Achievements To-Date

- Pilot scale pretreatment reactor has been constructed and commissioned
- Pretreatment has been tested on many local biomass raw materials
- High-severity pretreatment has been tested on lignin residues
- Small scale fermentation systems has been operated with corn stover as raw materials and the optimal fermentation process has been determined. First stage yields and productivities has been determined.
- Different separation methods have been identified and experimental systems for a side by side testing has been established
- The BioChemCat process has been modeled in ChemCAD and preliminary techno-economics over the process has been determined
- A outreach event is currently being planned involving besides the partners, Tricity Development Board (Tridec), the Mid Columbia Energy Initiative (MCEI) and WA Governor Jay Inslee

WSU Biomass Pilot Plant

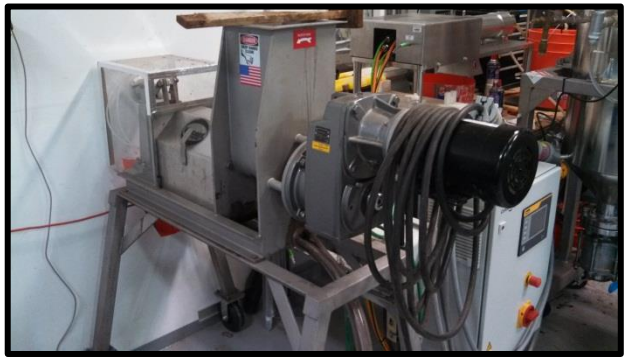


10 Liter Pretreatment Reactor



100 Liter Pretreatment Reactor (NEW)

400 Liter Fermentation Vessels (NEW)

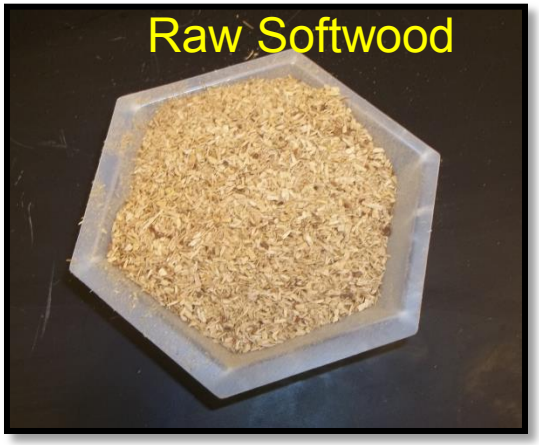


Screw Press Liquid/Solid Separation (NEW)

High Speed Centrifuge Liquid/Solid Separation (NEW)

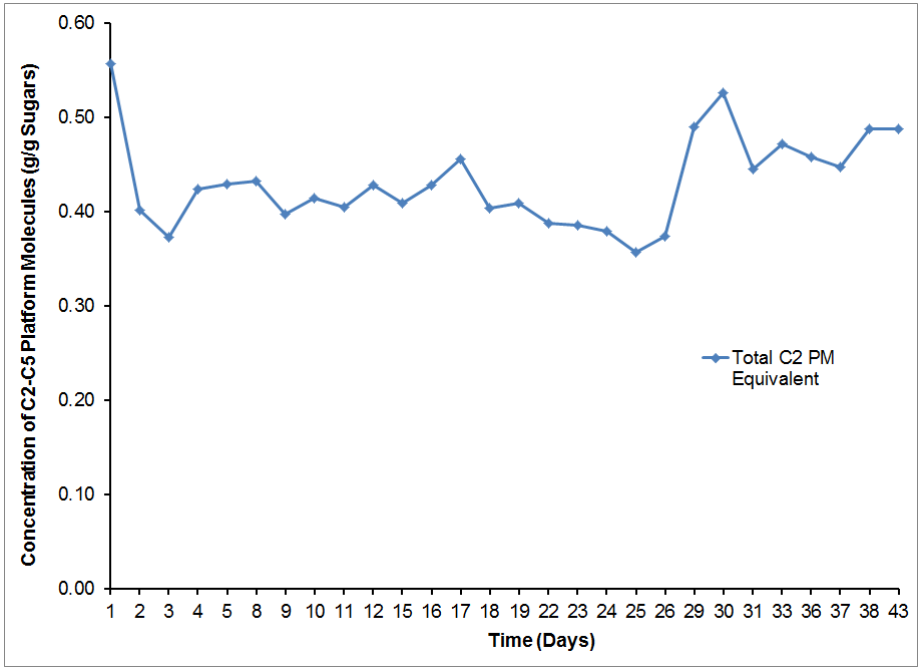
Softwood to Hydrolysate

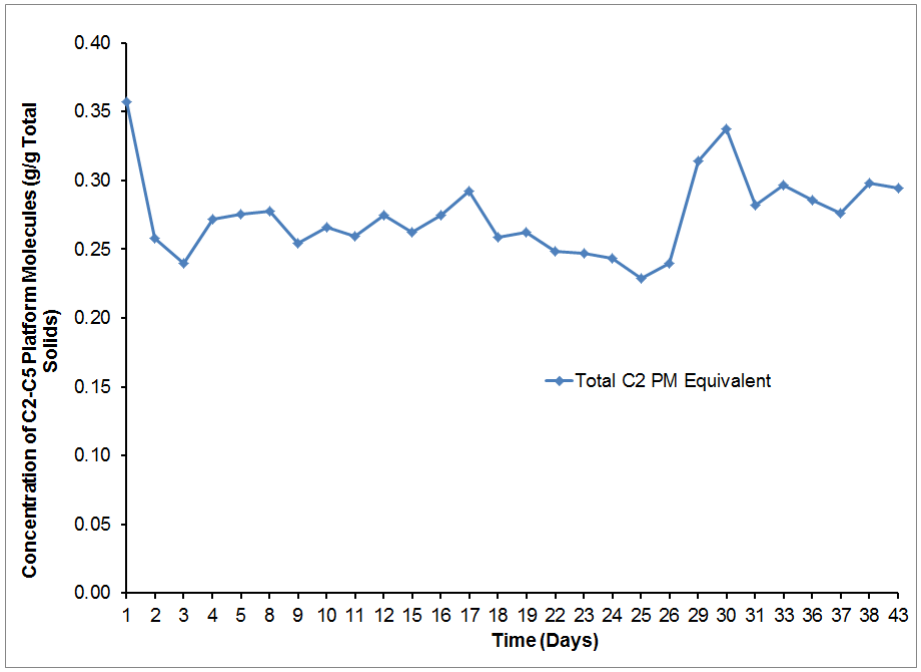
Milling



Pretreatment

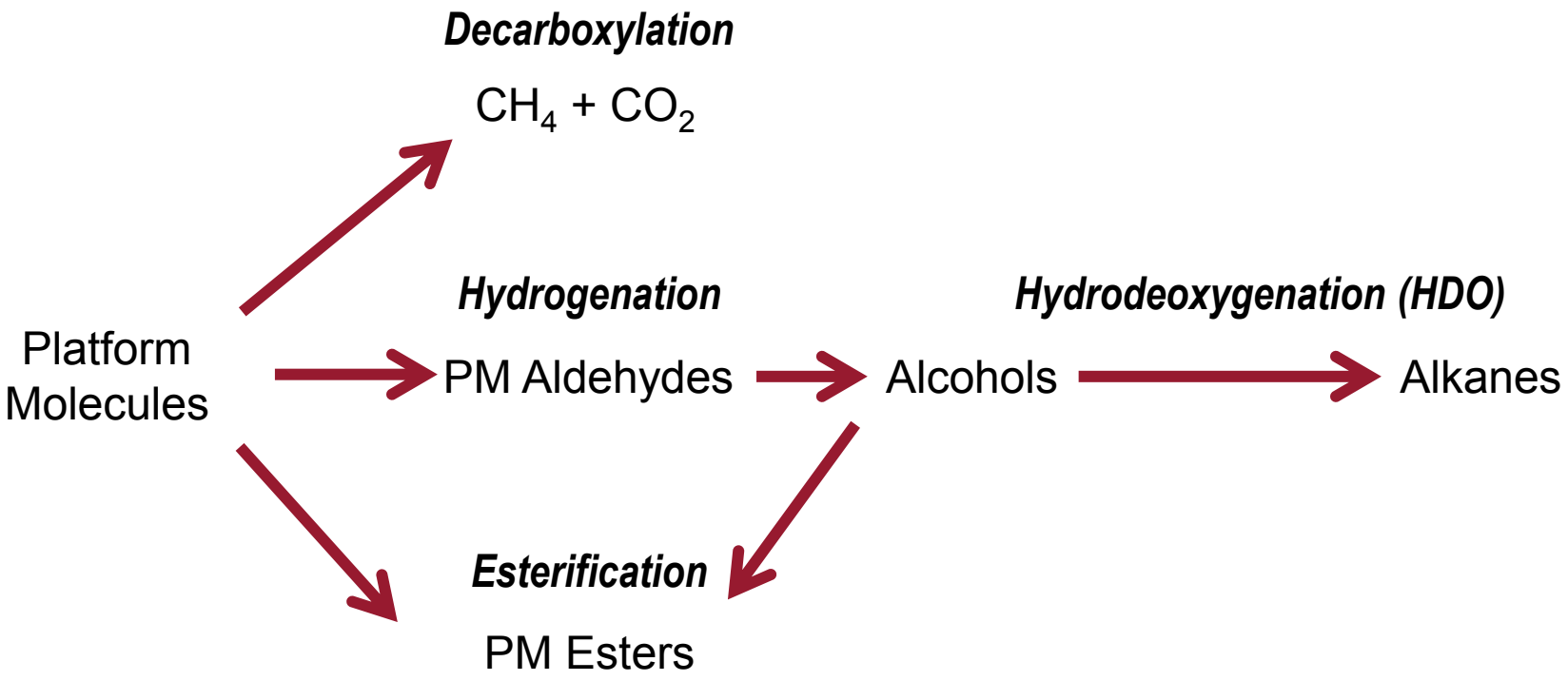
Platform Molecules (PM) Current Fermentation Results





Productivity: 0.4 g/L/h

Catalysis Process



Reaction Pathway for Conversion of Platform Molecules over Pd-Re/C Catalyst at 180-240°C (>95% Conversion to Alcohol @ Optimal Temperature)

Technoeconomic Data

Equipment Costs (2010$) (Biochemical)	Current Costs Capital Cost (MM$)	Intermediate Target Costs Capital Cost (MM$)	Final Target Costs Capital Cost (MM$)
Feedstock Handling	$ 6.31	$ 6.17	$ 5.83
Pretreatment	$ 40.04	$ 37.63	$ 35.87
Separation of PMs and Lignin	$ 74.55	$ 71.74	$ 69.38
Fermentation Organism Production	$ 65.85	$ 65.86	$ 65.86
Biogas	$ 21.75	$ 21.76	$ 21.76
Catalytic conversion & product recovery	$ 90.55	$ 83.50	$ 78.79
Wastewater Treatment	$ 38.57	$ 38.57	$ 38.57
Storage	$ 14.82	$ 14.82	$ 14.82
Civil Infrastructure (Bldgs., HVAC, etc.)	$ 24.46	$ 24.46	$ 24.46
Utilities	$ 48.10	$ 48.10	$ 40.90
Total Installed Capital	$ 425.00	$ 412.60	$ 396.24
Total Installed Capital per Annual Gallon	$8.50	$8.25	$7.92
Operating Costs (2010$)	MM$/yr	MM$/yr	MM$/yr
Feedstock	$ 42.86	$ 40.00	$ 37.50
Organism Production Nutrients	$ 1.50	$ 1.35	$ 1.25
Fermentation Nutrients	$ 3.00	$ 2.85	$ 2.70
Enzymes (Cellulase)	$ 0.00	$ 0.00	$ 0.00
Fermentation Organism (include licensing fees)	$ 10.00	$ 10.00	$ 10.00
Conversion Catalyst	$ 55.00	$ 28.00	$ 14.00
Other Raw Materials	$ 1.25	$ 1.20	$ 1.15
Waste Disposal	$ 5.00	$ 5.00	$ 5.00
Steam	$ 2.00	$ 2.00	$ 2.00
Electricity	$ 20.50	$ 19.50	$ 18.75
Labor and Maintenance	$ 26.45	$ 25.00	$ 23.75
Total Operating Costs	$ 182.56	$ 144.90	$ 121.10
Co-product Credits	$ 11.36	$ 10.60	$ 9.94
Net Operating Costs	$ 171.20	$ 134.30	$ 111.16
Net Fuel Production Costs ($/gal)	**$ 3.12**	**$ 2.49**	**$ 2.12**

Critical Success Factors

Technical Challenges:

- It is critical that a stable fermentation process can be established capable of fermenting variable biomass raw materials with high productivity
- It is critical that PM can be separated out and further can be upgraded into drop-in fuels with high yields

Market Challenges:

- Market is expected to be strong; but biofuels off-takers needs to be in place
- Biomass raw materials have been identified: but delivery and price needs to be negotiated

Commercialization Challenges:

- Investors will be necessary to bring the project up in demonstration scale. However, currently there is little appetite for biofuels projects with capital investments

BioChemCat: A Game Changing Technology

- It uses a stable consortia of bacteria and has no need for enzymes or sterility ***reducing the operational and capital cost significant*** (at least 15% reduction of OPEX compared to sugar platform biofuels)
- The stable consortia allows for changing between different biomass feed stocks for instance on a seasonal basis
- WEx pretreatment opens the lignin structure and allows for larger parts of the biomass to be converted into PM compared to other pretreatment methods
- The process can be operated in a spoke and hub manner allowing for distributed production of PM close to the biomass raw materials- and upgrading in a centralized hub
- The process allows for simultaneous production of chemicals and drop-in biofuels buying down the cost of biofuels production
- Bolt-on to a corn ethanol plant is possible sending the C6 sugar to the corn ethanol facility and using all other fractions as input to the BioChemCat process

Future Work

- The plan for the coming 11 month is to expand the pilot testing from pre-processing, pretreatment of biomass raw materials to 400 L fermentations of selected local biomasses. Further to add PM separation in pilot scale after the selection of method. Finally to finish techno-economics of the BioChemCat process.

Key Milestones

- *Increase productivity to 0.75 g PM/L/h (no decision point as 0.35 g PM/L/h is already met)*
- *Test different separation methods in a side by side comparison (go/no go decision to select 1 method to go into pilot testing)*
- *Test of catalysis using work done by PNNL on pure substrates (go/no go decision for technology. Fall back solution: using catalysis pathways going via ethylated esters*
- *Produce a techno-economic analysis based on results from the pilot testing whereby drop-in fuel alone can be produced for $2.5 per gallon within an intermediate perspective (investor decision point)*

Summary

1) **Approach:** BioChemCat is an innovative new approach for making biofuels/bioproducts
2) **Technical accomplishments:** The project with its extended timespan is fully on track and has already proven that the concept is viable
3) **Relevance:** The project has direct relevance fore DOE's mission of decreasing US's dependence of foreign oil. It further shows ways for better use of biomass and organic waste in general. All in all- the BioChemCat could allow for a new successful US based business
4) **Critical Success factors and challenges:** With the results obtain until now the technical challenged all seems possible to overcome. The dry investor environment could be the most critical success factor and challenge.
5) **Future Work**: In the coming period the fermentation process will further upscale to pilot scale along with the selected separation method. After finalizing the techno-economics the process is ready for further up scaling.
6) **Technology transfer**: Different outreach activities are planned for the coming period around the BioChemCat project. CleanVantage will further work for setting up licensing agreements around their IP.

Special thanks to my group and collegues at BSEL, the Port of Benton, CleanVantage and PNNL.

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QUESTIONS?