Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

DOE Bioenergy Technologies Office (BETO)
2015 Project Peer Review

2.1.0.301 Analysis & Sustainability Interface

MARCH 23, 2015
CONVERSION

Sue Jones
Pacific Northwest National Laboratory

Goal Statement

- **Enable thermochemical R&D of sustainable, economic biomass derived liquid fuels by:**
  - Performing techno-economic analysis (**TEA**)
  - Identifying **cost reduction opportunities** for researchers
  - Providing input to **sustainability** analysis

- **This project directly supports BETO's goals to:**
  - "*Enable **sustainable**, nationwide **production of biofuels** that are **compatible with** today's **transportation infrastructure**, can **reduce greenhouse gas emissions** relative to petroleum-derived fuels, and can **displace a share of petroleum-derived fuels** to reduce U.S. dependence on foreign oil.*
  - *Encourage the creation of a new domestic bioenergy and bioproduct industry.*" (Nov. 2014 MYPP)

Quad Chart Overview

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Timeline

- October 1, 2010
- September 30, 2017
- Percent complete: 69%

Budget

	Total Costs FY 10–FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding FY 15-FY17
DOE Funded	$774K	$464K	$494K	$2,568K

Addressing Evolving Research Needs

FY10-12	Pyrolysis oil upgrading
FY13-14	Pyrolysis oil upgrading, syngas conversion to distillates
FY15	Pyrolysis oil upgrading, syngas conversion to distillates, sustainability

Barriers

- Barriers addressed
  - **At-A**: Comparable, transparent and reproducible analysis
  - **St-C**: Sustainability data across the supply chain
  - **Tt-R**: Process Integration *(thermochemical conversion)*

Partners

- Interactions/Collaborations:
  - ANL: life-cycle analysis
  - INL: feedstocks
  - NREL: techno-economics
  - External reviewers

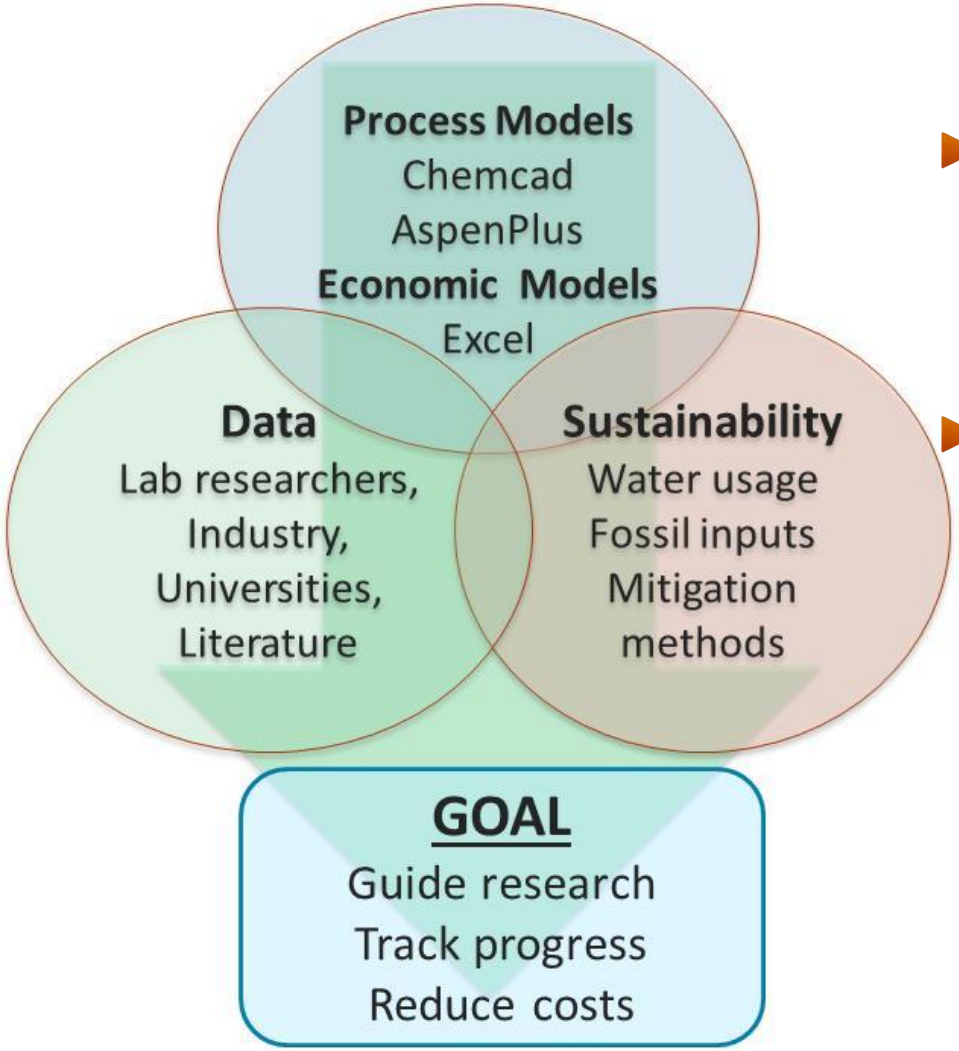
Project Overview

- **Timeline for Thermochemical Conversion Analysis**
  - **FY10-FY11:** prepared State of Technology (**SOT**) analysis for pyrolysis and upgrading based on design case published 2009
  - **FY12**: **annual SOT** for pyrolysis and upgrading; began TEA for **new thermochemical pathways**
  - **FY13-14:** Updated **pyrolysis design case**; prepared preliminary TEAs for **syngas conversion** scenarios
  - **FY15:** Continued TEA for pyrolysis and syngas; project combines with formerly separate sustainability analysis project
- **Context: Economic** and **sustainable** biofuel production via thermochemical conversion
- **Key Objective:** use experimental results and projected commercial scale mature plant costs, with consistent assumptions to **support BETO's 2017 demonstration targets** and provide information for public use

Approach (Technical)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

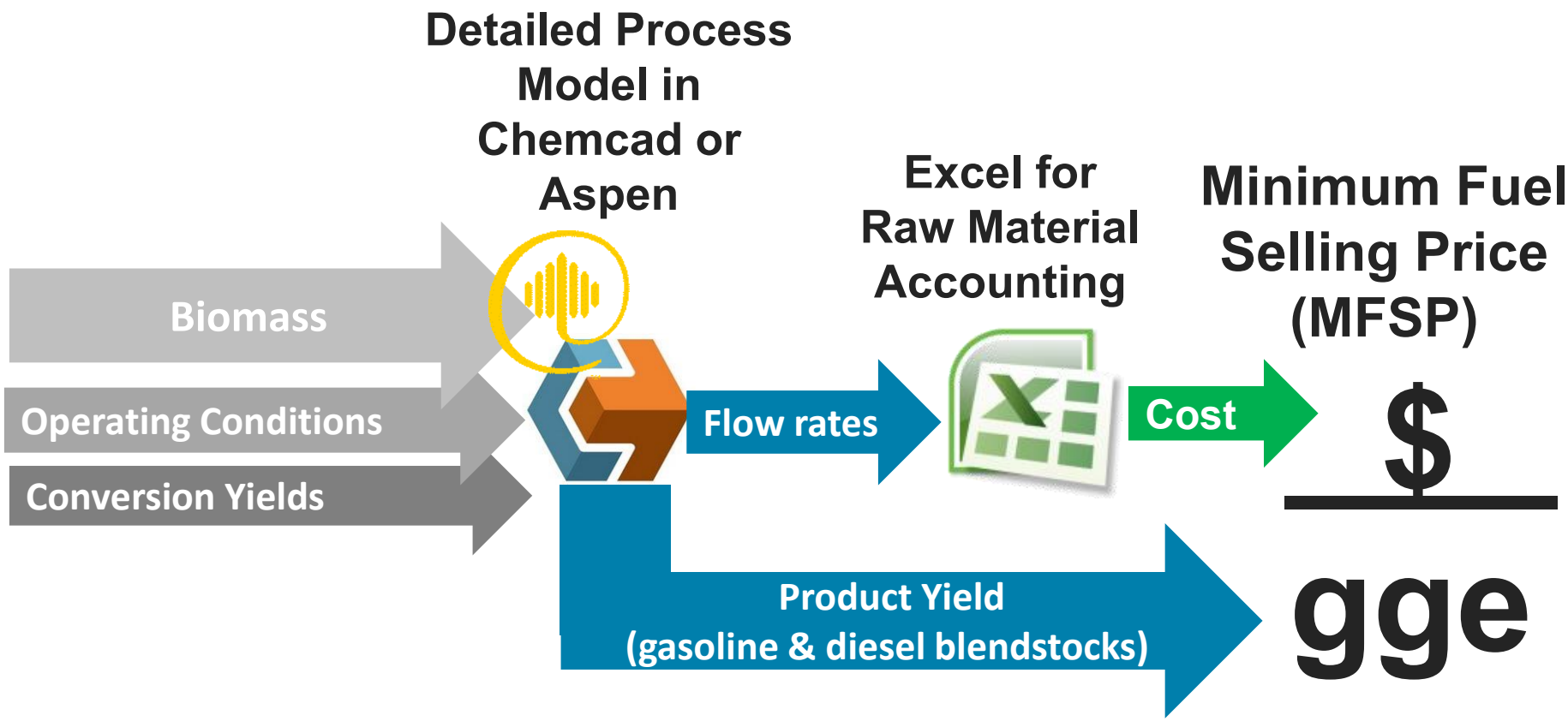
Approach structure



- **Approach** **Consistent** use of **BETO** technical and financial **assumptions** (detailed later)
- **Critical Success Factors**
  - Identify **cost reduction** strategies
  - Help **set research goals**
  - Quantify **sustainability impacts**
- **Potential Challenges – risk and uncertainty:**
  - **Sensitivity** studies to **identify** high **cost impact** areas
  - Conclusion uncertainties **risk management**:
    - External peer review
    - Interaction with industry
    - Multi-lab collaborations
    - Make assumptions transparent

Approach (Technical)

- **Approach** Same methodology used across all labs



Approach (Management)

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- **Approach structure**
  - **Project Management Plan** (PMPs) in place indicating scope, budget and schedule
  - **Annual Operating Plans** (AOPS) prepared prior to each fiscal year: Details quarterly **milestones** and **deliverables**
  - **Quarterly reporting** to BETO (written & regularly scheduled calls)
- **Potential challenges**
  - **Data availability**: timely and frequent communication with researchers and ongoing review of industry and university work
  - **Researcher proximity**: scheduled calls & data exchanges with INL, NREL and ANL for collaborative work
- **Critical success factors**
  - Make **results public** (MYPP and published reports)
  - **Deliver** quality work **on-time**, **on-budget**

Technical Accomplishments since 2013 Review (Overview)

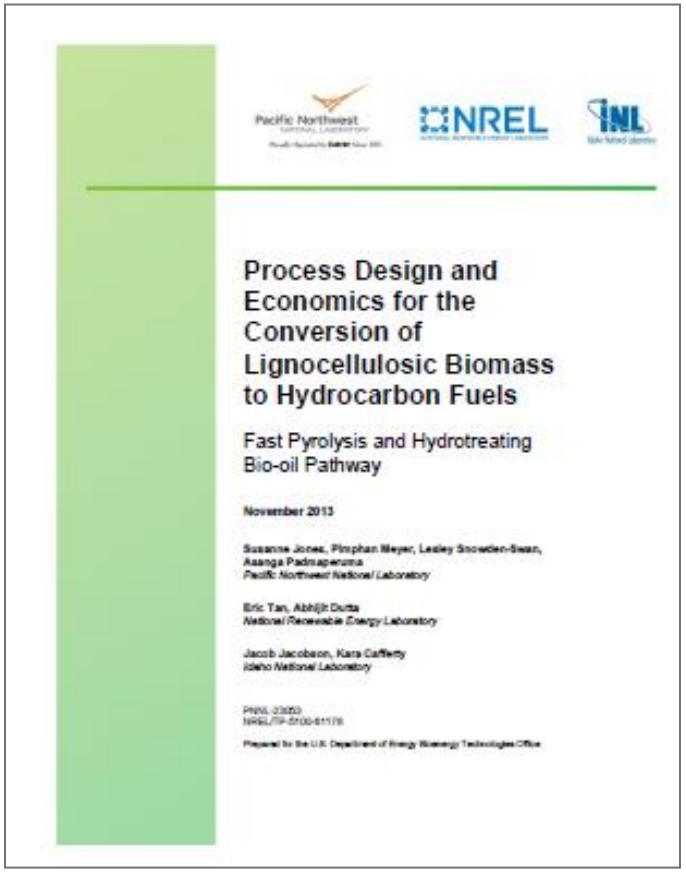
- **Biomass to gasoline and diesel blendstocks via pyrolysis and bio-oil upgrading (focus of presentation)**
  - **Updated design report published** : peer reviewed, co-authors with NREL (alternative hydrogen plant scenario), and INL (feedstock)
  - **Updated targets** leading to 2017 design case
  - Developed **multiple sensitivity scenarios** for experimentalists leading to FY14,15 and FY16 cost targets
  - **Published SOT reports** for each year since 2011
  - Supported ANL's supply chain **sustainability analysis** (SCSA) for this conversion process (2015)
- Contributed literature review, experimental input and sustainability analysis for NREL's **Catalytic Pyrolysis** Design report (2014)
- **Syngas conversion**
  - Completed alternate syngas pathways milestone report with NREL (April 2014)
  - Provided sustainability analysis for NREL's Syngas to High Octane Gasoline design report (2014)
  - Prepared comparative economics for PNNL researchers for 4 syngas to distillates routes (December 2015)

Technical Accomplishments: Updated Pyrolysis & Oil Upgrading Design Report

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

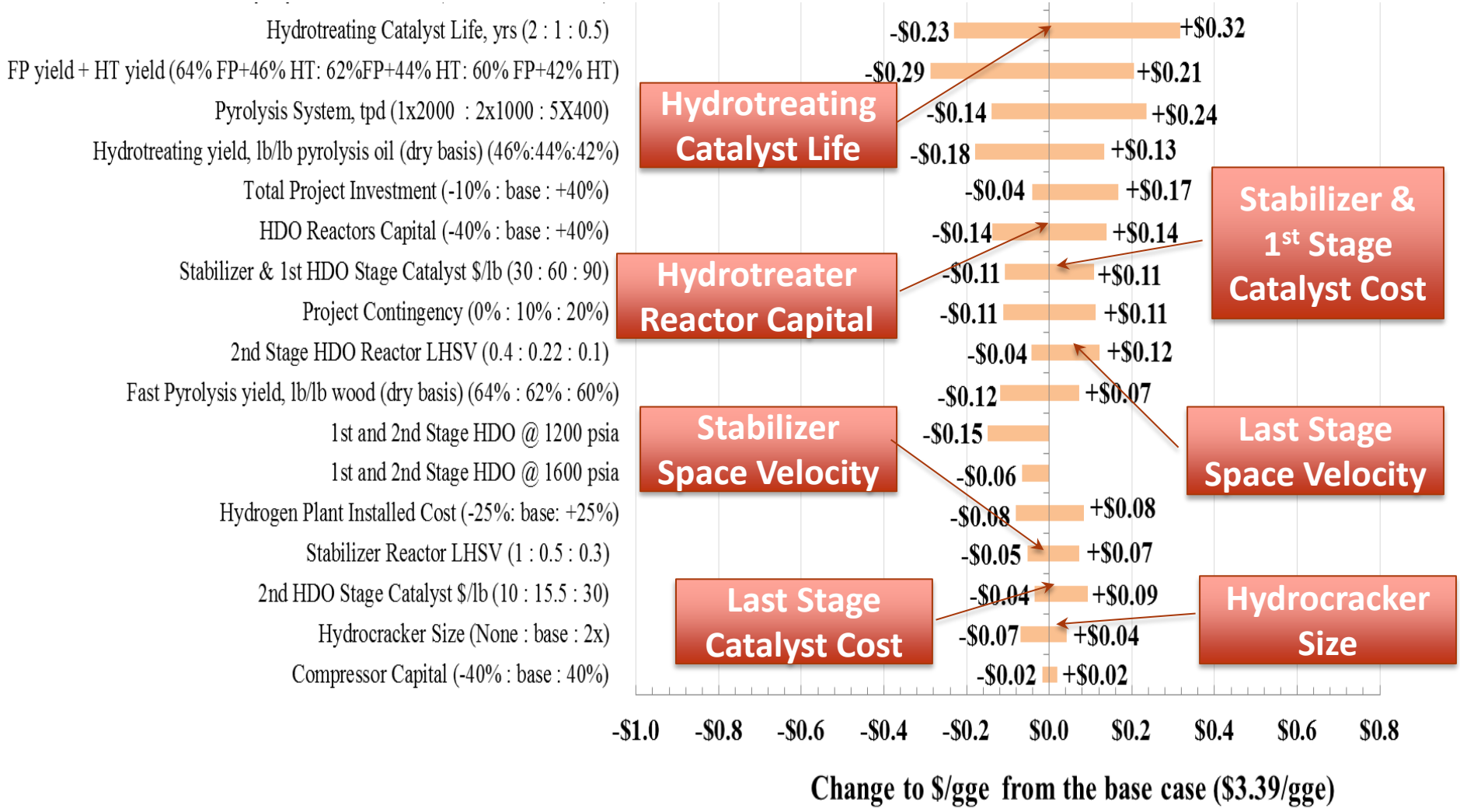
- **Published November 2013** (updates 2009 literature based report); directly supports BETO's 2017 conversion targets
- Incorporates **experimental data** to date
- **Revised upgrading scheme** to reflect current understanding of oil upgrading
- **Key assumptions – BETO Standard**
  - 2000 dry metric tonnes per day biomass
  - $80/dry ton feedstock
  - 40% equity financing, 10% IRR
  - 60% debt financed at 8% for 10 years
  - Costs in 2011 $ for a mature nth plant
- **Peer reviewed** by subject matter experts from 6 institutions (industry & university). Reviewers and review comments provided to BETO
- **Sustainability metrics** included

Multi-lab effort: PNNL, NREL, INL



Technical Accomplishments: Design Case 2017 Target Case Sensitivities

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965



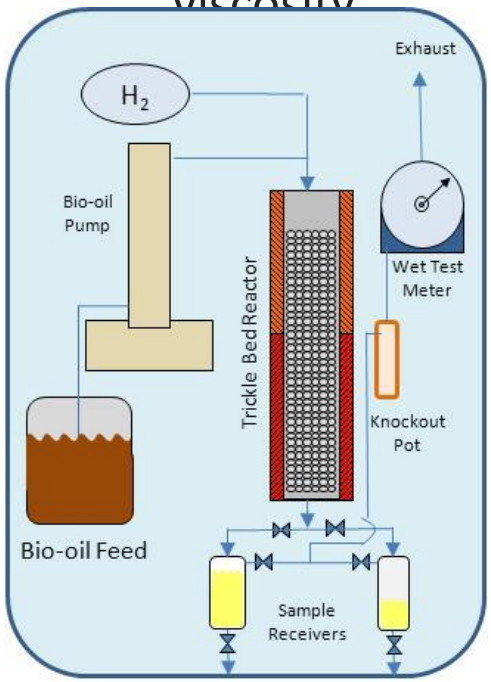
- Key element of TEA - shows high impact cost areas
- Catalyst related costs (combined) the most significant

Technical Accomplishments: Pyrolysis Oil Upgrading – Experimental Data used in Models

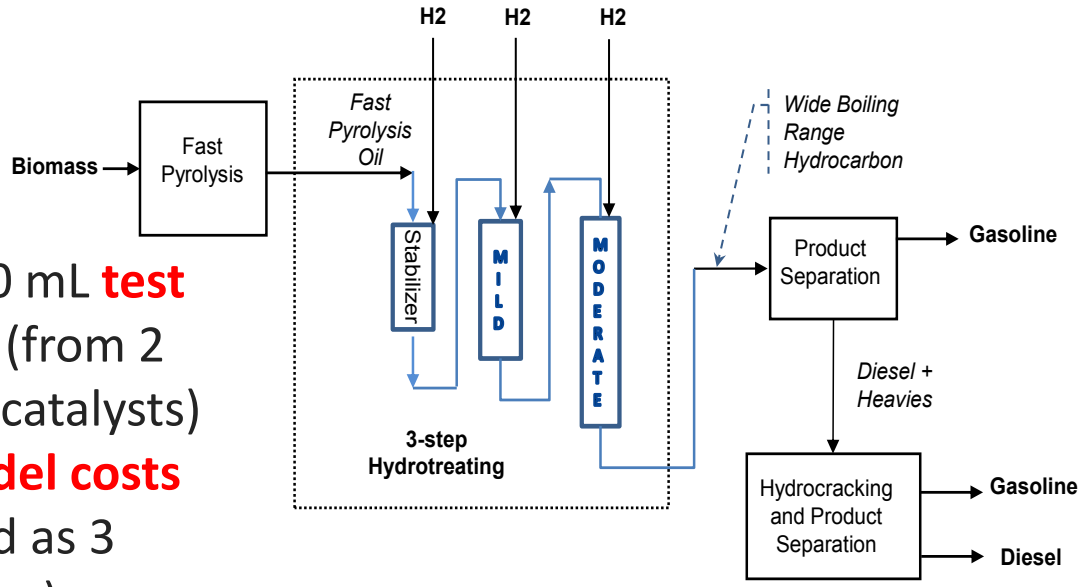
Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Modeled as a Three Reactor System

- First reactor is for stabilization
- Then 2-stage hydrotreating (single reactor test stand)
  - 2 bed system using 2 different heat zones and space velocities
  - Ru/C followed by NiMo/alumina
  - Adjust **temperature** and **space velocity** to determine effects on **density** and **oxygen content**
  - Product analysis for simulations: SimDis, GC/MS, CHNOS, density, TAN, viscosity



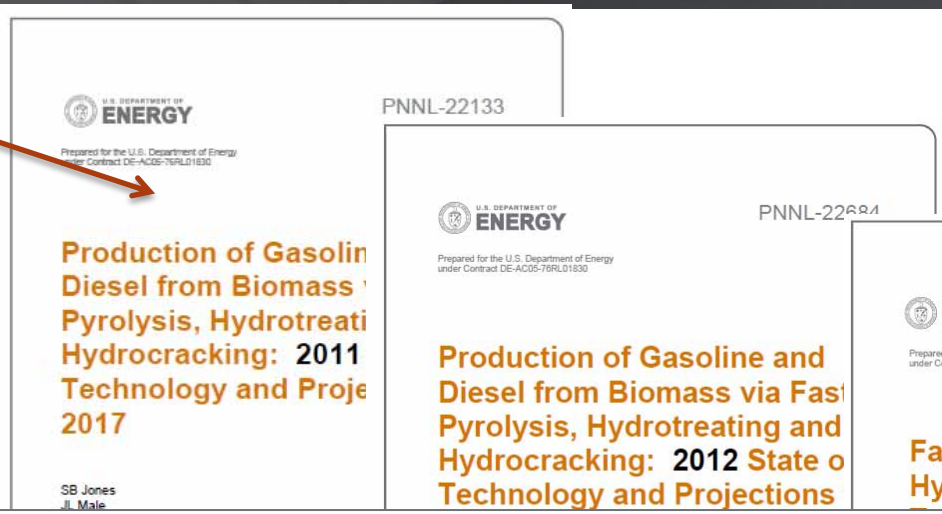
30 mL & 400 mL **test stand data** (from 2 reactors & 3 catalysts) used to **model costs** (modeled as 3 reactors)



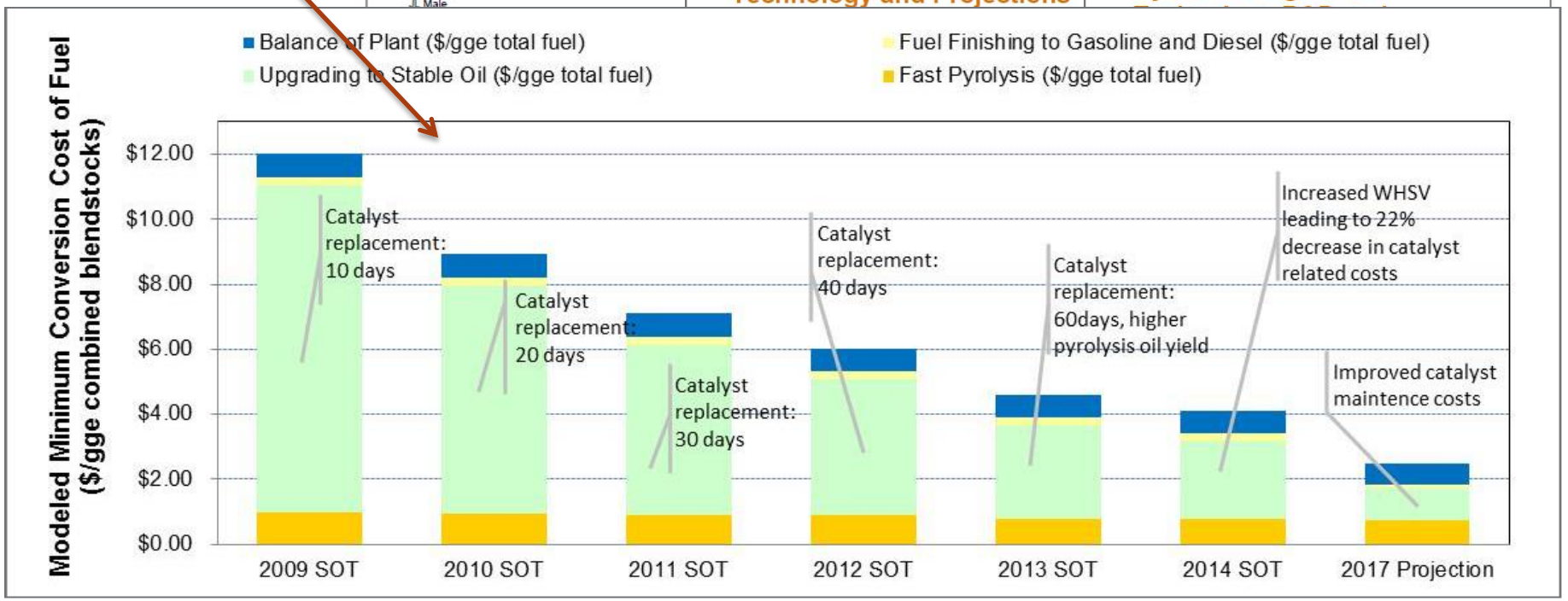
Technical Accomplishments: Fast Pyrolysis & Upgrading Past Performance and Future Targets

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Publishing annual SOTs provide cost reduction details for Fig. 2-27 in the MYPP



SOT also includes current industry & university status



Technical Accomplishments: Pyrolysis and Upgrading Sustainability Metrics

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Sustainability Metric for Conversion Process	2009 SOT	2012 SOT	2013 SOT	2014 SOT	2017 Projected
Fossil GHGs (g CO_2-e/MJ fuel)	22.1	19.8	20.5	19.4	18.9
Fossil Energy Use (MJ fossil energy/MJ fuel)	0.33	0.29	0.32	0.31	0.30
Fuel Yield (gal/dry ton wood; GGE/dry ton wood)	74; 78	74; 78	84; 87	84; 87	84; 87
Carbon-to-Fuel Efficiency (%biomass C in fuel product)	38	38	47	47	47
Water Consumption (m^3/day; gal/GGE)	998; 1.5	998; 1.5	1124; 1.5	1088; 1.5	1050; 1.4
Wastewater Generation (m^3/day; gal/GGE)	917; 1.4	917; 1.4	948; 1.3	975; 1.3	932; 1.3

- **Sustainability Metrics** are also included in the **MYPP** (note these are for conversion only-INL provides feedstock metrics)
- Serves as **input to** life cycle analysis (ANL provides full **LCA**)
- **Informs** modeled plant **choices** (e.g. air fins vs. water cooling)

Technical Accomplishments: Major Pyrolysis and Upgrading TEA Performance Metrics

Abbreviated MYPP Appendix B – further shows where improvements needed

Process Parameter	2013 SOT	2014 SOT	2015 Projection	2016 Projection	2017 Projection
Yld Combined Blendstocks, GGE/ton	87	87	87	87	87
Pyrolysis Oil Yield, lb organic / lb dry wood	0.62	0.62	0.62	0.62	0.62
Upgraded Oil C Efficiency, wt% pyrolysis oil	68	68	68	68	68
Natural Gas Usage, scf / dry US ton	1,685	1,742	1,685	1,685	1,685
Upgrading Catalyst Cost, mm$ / yr Annual cost is a function of: WHSV, number of reactors, catalyst replacement rate, and $ / lb	**130**	**97**	**80**	**43**	**19.4**

Technical Accomplishments: Collaborations with Researchers - Progress to 2017 & Cost Reduction Opportunities

- **Increased space velocity**
  - **LHSV** (v/h/v catalyst) reduces reactor **capital** (sets reactor size)
  - **WHSV** (w/h/w catalyst) reduces **operating** costs (sets catalyst fill)
- **Reduced catalyst replacement costs for stabilizer and 1st upgrader**
  - Stabilizer & 1st upgrader use **7.8 wt% ruthenium** loading on a **carbon support**
  - Lower ruthenium loadings and/or less expensive metals
  - **Less expensive supports** amenable to simple regeneration
- **Increased time on stream before complete catalyst change needed**
  - Eliminates need for **hot spare reactors**
  - ***In situ* catalyst regeneration** one way to mitigate short catalyst life
- **Improved upgraded product and individual fuel products**
  - Working towards **characterizing fuel** cuts
  - Provides better understanding of **upgrading effectiveness**
- **Consider hydrocracking requirements**
  - Quantify fuel yield from **heavier than diesel cut** from the upgraders
  - Estimate need for **further ring saturation** of the diesel cut to meet cetane

Technical Accomplishments: Collaboration with Researchers - Cost Reduction Opportunities

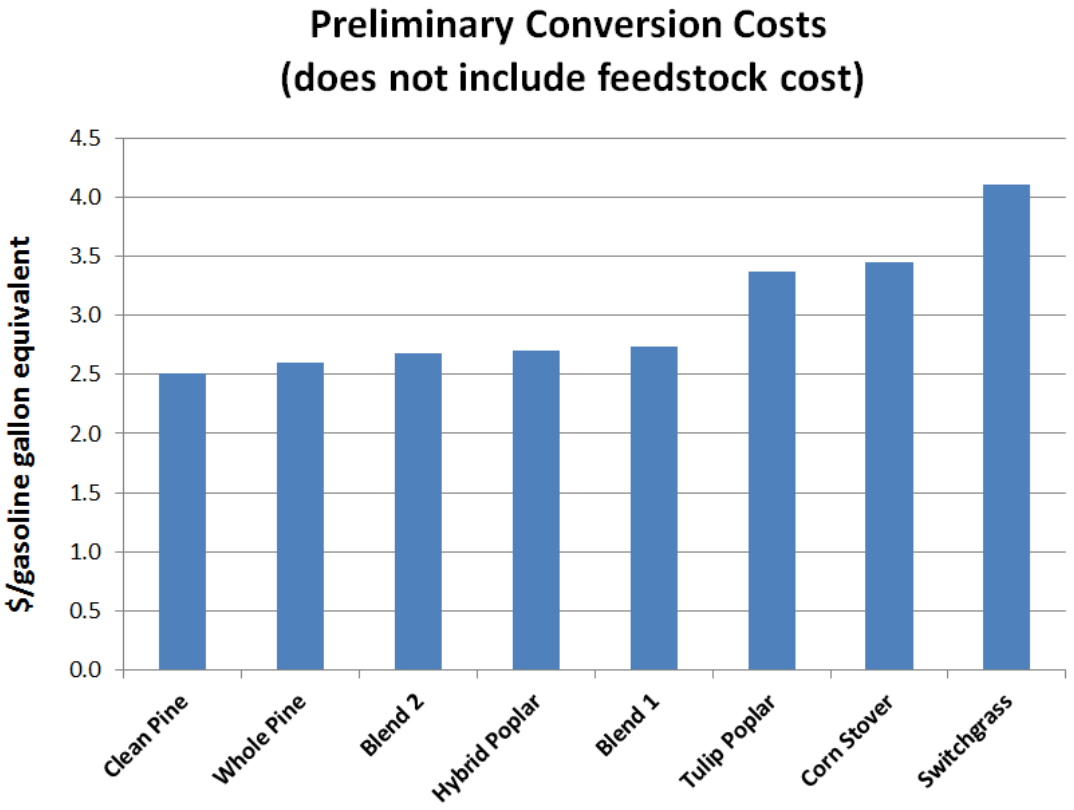
- **Need combination of effects** to get from 2014 SOT to 2017 Projected
- **Ran** several dozen **combination cases**
- Example **cost reduction strategies** that meet the 2015 conversion cost targets are shown below

Catalyst $/lb		Cat Life, days		LHSV			Explanation
Stablzr	1st bed	1st bed	2nd bed	Stablzr	1st bed	2nd bed	
70	70	60	60	0.5	**0.5**	0.22	Increase 1st bed LHSV from 0.3 to 0.5
51	**51**	60	**90**	0.5	0.3	0.22	5% Ru catalyst for stabilizer & bed 1, plus a 90 cat life for bed 2
70	70	**90**	**90**	0.5	0.3	0.22	90 day life for beds 1 & 2

- Informs the experimentalists
- Informs other analysis, such as the Computational Pyrolysis Consortium

Technical Accomplishments: Collaboration with Researchers - Feedstock Effects

- **TEA** and **sustainability** impacts of **pure** and **blended feedstocks**
- Experimental data from **Feedstock Interface Project** (INL, NREL, PNNL)
- **High level estimated conversion costs shown here**
- Currently completing **detailed cost and performance models** for input into sustainability and sensitivity analysis

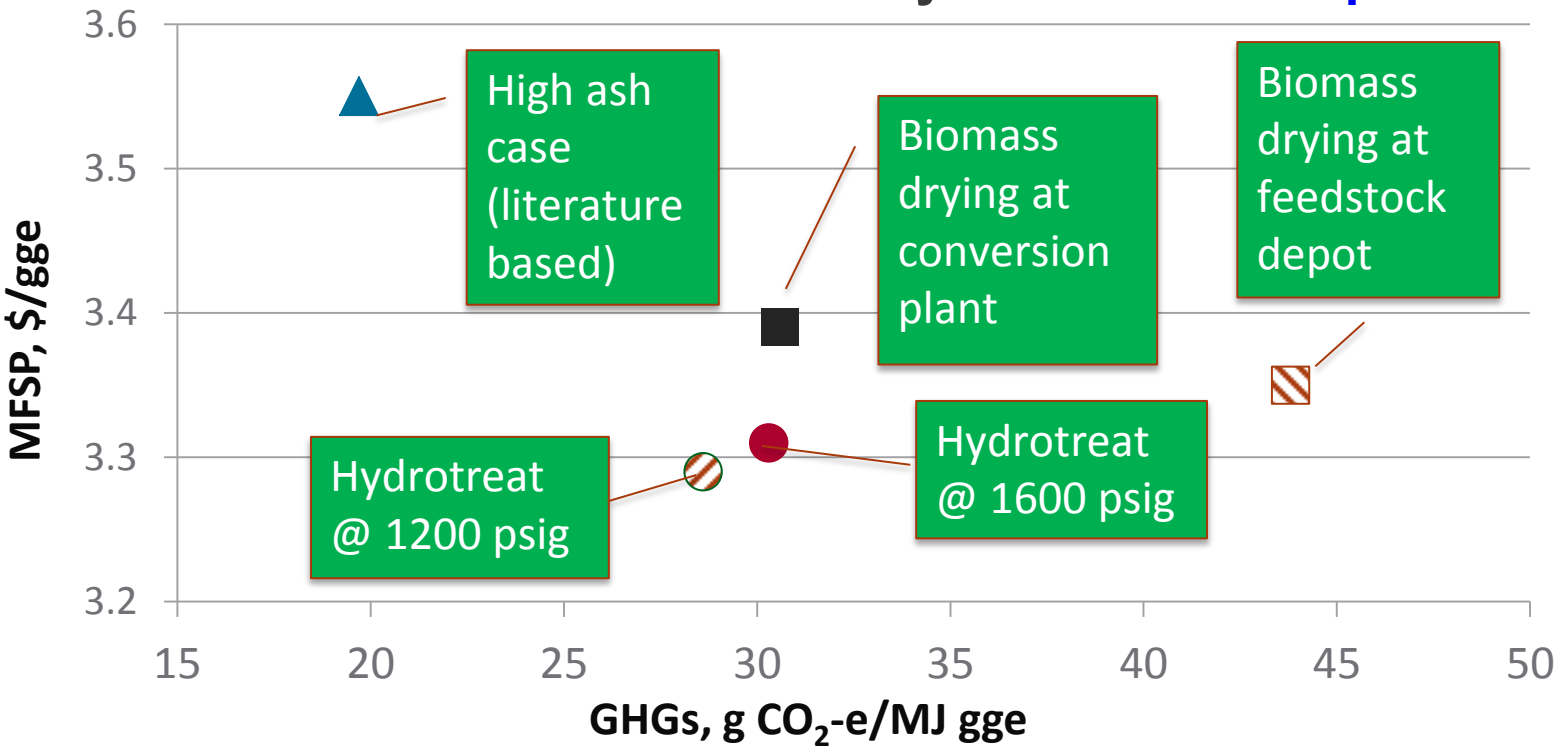


- **TEA journal publication** draft to be completed in September
- Will include feedstock costs and sensitivity analysis

Technical Accomplishments: Collaboration with Researchers - Sustainability

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Economics and Sustainability Trade-off Example



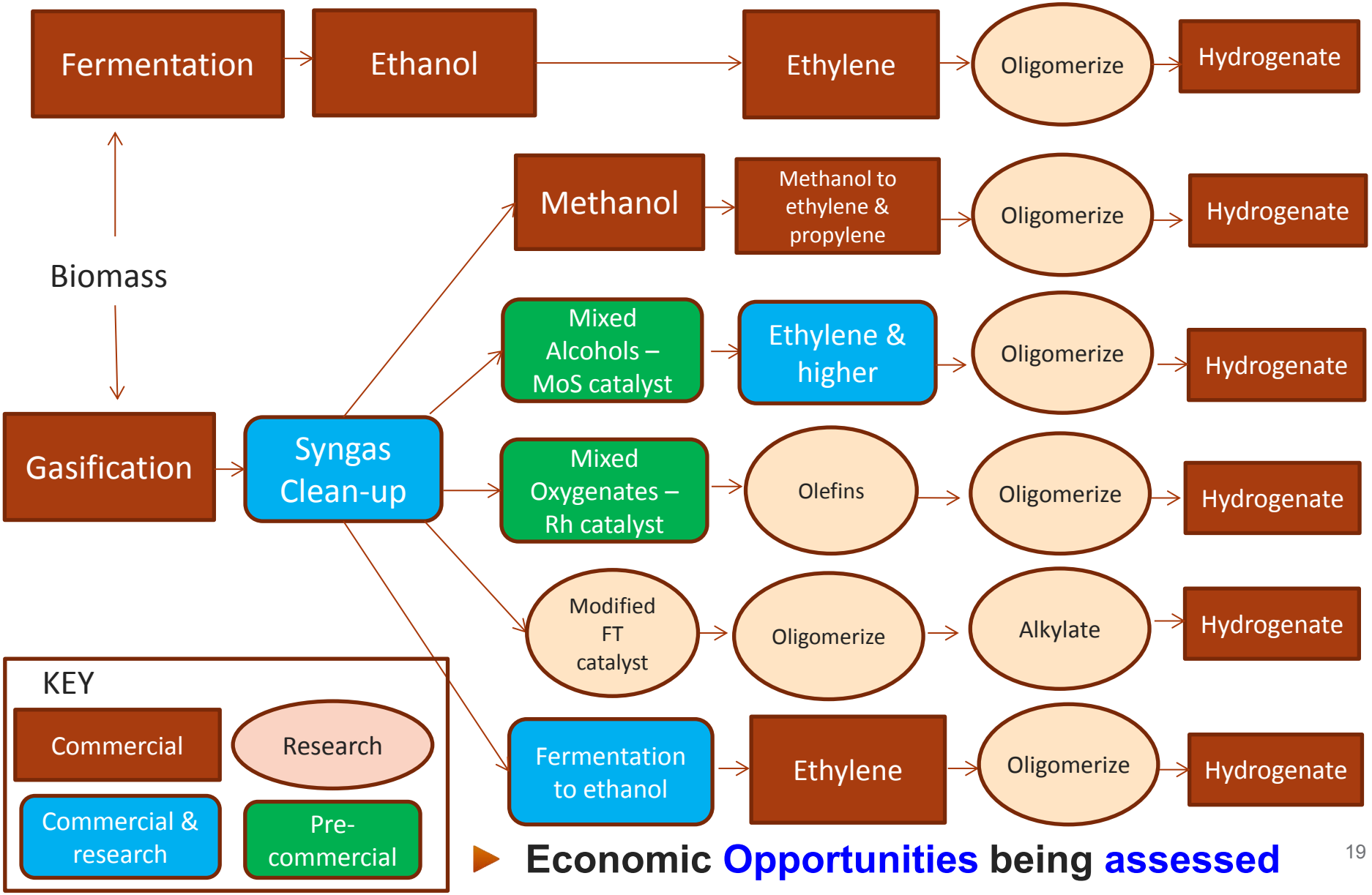
Observations from Life-cycle Analysis (based on processing forest residues)

- **Reducing hydrotreater pressure**: reduced cost (↓ capital and electricity) & GHGs (↓ electricity)
- **Higher feedstock ash content** reduces GHGs (↓ NG), increases MFSP (↓ yield)
- Moving the **dryer offsite** slightly reduces conversion cost, but increases GHGs (↑ NG)

Note: in related work ANL performing LCA for SOT based on INL feedstock specifications

Technical Accomplishments: Collaboration with Researchers - Syngas Conversion to Distillates

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965



- **Economic Opportunities being assessed**

Technical Accomplishments: External Collaborations

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- **NREL's Design Case for Catalytic Pyrolysis & Upgrading**
  - Provided literature review of catalytic pyrolysis reported yields
  - Completed sustainability analysis
- **NREL's Design Case for Syngas to High Octane Gasoline**
  - Completed sustainability analysis
- **ANL's** Supply Chain Sustainability Analysis (**SCSA**)
  - Provided input and review for the fast pyrolysis and upgrading pathway
  - SCSA documents the full **LCA for the GREET** model

Technical Accomplishments: PMP Metrics Since FY13 Review

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Description	Due Date	Completed
Complete 2012 SOT Table for FY13 MYPP	Mar-13	on-time
Draft update for pyrolysis pathway for external review (with NREL)	Jun-13	on-time
Complete revised design case for the pyrolysis pathway (with NREL)	Sep -13	on-time
Complete Annual SOT Update for Pyrolysis	Dec-13	on-time
Complete 2013 SOT Table for FY14 MYPP	Mar-14	on-time
Draft in situ and ex situ catalytic pyrolysis reports for external review (with NREL)	Jun-14	on-time
Complete in situ and ex situ catalytic pyrolysis reports (with NREL)	Sep-14	on-time
Updated pyrolysis SOT target table showing progression towards the programmatic goal of $3/gge, including sustainability metric updates	Dec-14	on-time
Completed pyrolysis SOT report detailing technical accomplishment completed to meet the 2014 targets, including sustainability metric update	Mar-15	In progress
Draft oxygenates to distillates design case completed for external review (with NREL), including sustainability metrics	Jun-15	In progress
Complete a manuscript draft to be submitted to a peer-reviewed journal on integrated TEA/sustainability analysis that will focus on key uncertainties/sensitivities around bio oil based fuel production processes and identify trade-offs and/or synergies among economics and sustainability metrics. This will facilitate better informed biorefinery design decisions for optimized cost and sustainability performance.	Sep-15	In progress

Project Relevance

- **Directly supports BETO Thermochemical Conversion Goals:** "*By 2017, achieve an nth plant **modeled conversion cost of $2.50/gge** via a thermochemical pathway*" (November 2014 MYPP)
  - Assists researchers in defining **technical targets** to be achieved experimentally
  - Provides the associated **modeled production costs** indicating high impact research areas for conversion and feedstock types
  - Pyrolysis Oil Upgrading modeled progress published annually in the **MYPP** (Section 2.2.2 and Appendix B)
  - Published **annual SOT** reports in support of MYPP input and Includes industry and university status
  - Worked with **industry, laboratory** and **university partners who provided review for** the updated design case TEA projecting 2017 targets
  - Design case contains detailed process inputs and results **published** and **available for use by stakeholders** (industry, universities, other research organizations)

Project Relevance

- This project also provides **analysis** input to researchers indicating cost-reduction opportunities for other **viable thermochemical conversion routes** (catalytic pyrolysis, syngas to gasoline and to jet & diesel) supporting:
  - "By 2015, select at least one thermochemical pathway for initially integrated operations to validate the Office's performance goal of $3/GGE by 2017 by evaluating R&D data from bench-scale, semi-integrated thermochemical pathways that produce gasoline and diesel blendstock fuels." (Nov. 2014 MYPP)

- **BETO Barriers addressed**
  - **At-A**: Comparable, transparent and reproducible analysis
  - **St-C**: Sustainability data across the supply chain
  - **Tt-R**: Process Integration *(thermochemical conversion)*

Future Work

- **Next 18 months: continue to support BETO**
  - **Pyrolysis & Upgrading:**
    - Complete annual SOT for input into the MYPP
    - Complete analysis of pure and blended feedstocks for **peer reviewed journal** submission
    - Work with experimentalists and analysts to capture key information and provide **insights** into areas of **potential cost reduction**
  - **Syngas to Distillates:** complete TEA portion of peer reviewed journal article drafts detailing experimental catalyst data
  - **Sustainability:** continue to integrate sustainability metrics with economics to understand the tradeoffs
- **Key milestones and deliverables**:
  - 2014 Pyrolysis and Upgrading SOT report publication (3/2015)
  - Collaborate with NREL on syngas to distillates economics (9/2015)
  - 2015 Pyrolysis and Upgrading SOT waterfall to BETO for inclusion in the MYPP (9/2016)

Summary

Overview: **Techno-economic** and **sustainability analysis** for thermochemical conversion pathways

Approach: **Iterate** TEA and sustainability analysis **with researchers** to identify areas for cost reduction

Technical Accomplishments/Progress/Results

- FY13: Completed updated Pyrolysis Design Report and 2012 SOT
- FY14: Published Design Report and SOT
- FY15: 2014 pyrolysis and upgrading SOT completed; completed analysis of 4 syngas to distillates pathways

Relevance: by assessing conversion processes this project **aligns with BETO's ultimate mission** to reduce dependence on petroleum and achieve cost parity with conventional transportation fuels; In the near term it directly **supports BETO's 2017 goals**.

Future work: Conversion SOT analysis for MYPP, fuel production costs for various feedstocks and syngas conversion analysis

Status since 2013 Review: project ongoing, expanded collaborations with other labs

Acknowledgements

- **Bioenergy Technologies Office**
  - Conversion: Kevin Craig, Liz Moore, Prasad Gupte
  - Analysis & Sustainability: Zia Haq, Alicia Lindauer, Kristen Johnson

PNNL	NREL	INL	ANL
Pimphan (Aye) Meyer	Abhijit Dutta	Jake Jacobsen	Jennifer Dunn
Lesley Snowden-Swan	Eric Tan	Kara Cafferty	Zhichao Wang
Alan Zacher	Michael Talmadge	Tyler Westover	Michael Wang
Mariefel Olarte	Daniel Carpenter		
Douglas Elliott	Mary Biddy		
Daniel Howe			
Corinne Drennan			

Additional Slides

- Response to comments from 2013 Review
- Publications & Presentations
- List of abbreviations

Responses to Previous Reviewers' Comments

- **2013 Review Comments**:
  - *"The work on the design case is high in quality and proceeding as planned. The inclusion of sustainability is excellent and it is good to see that the design case is being reevaluated to include new information that has been available in the last two to three years."*
  - **Response:** the revision to the original design case has been redone as a collaborative effort with INL and NREL. Additionally, external reviewers provided extensive feedback to the design case, which was incorporated. Updated capital costs for the pyrolysis system came from industry and the hydrotreating section was reviewed by an external engineering firm. Lastly, increased emphasis on sustainability impacts have been included.
- **2013 Review Comments**:
  - *"While the goal of modeling the process concepts and assessing costs is laudable, the influence of government mandates might be producing results that lack the credibility that other nongovernmental analysis programs can provide….If the progress was as described, money would be flooding in to build demonstration and commercial plants."*
  - **Response**: It is unfortunate that the presentation did not make clear the underlying purpose for this work. BETO uses national laboratory research along a specific pathway as a means to set goals and measure progress using data, methods and assumptions that are public and are well documented. It is understood that the analysis basis may not be what a commercial entity would use to assess whether or not to pursue a given process. Instead, the financial assumptions used by the office are established as a common language for assessing the relative differences between differing pathways on a well understood basis. The estimates do not reflect pioneer plant costs, as these will vary greatly between pathways, but instead a future conditions (nth plant) where the processes are mature.

Publications & Presentations

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Publications

- Zhu Y, SA Tjokro Rahardjo, C Valkenburg, LJ Snowden-Swan, SB Jones, and MA Machinal. 2011. "Techno-economic Analysis for the Thermochemical Conversion of Biomass to Liquid Fuels." PNNL-19009, Pacific Northwest National Laboratory, Richland, WA http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-19009.pdf
- Snowden-Swan LJ, and JL Male. December 2012. Summary of Fast Pyrolysis and Upgrading GHG Analyses. PNNL-22175, Pacific Northwest National Laboratory, Richland, WA http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22175.pdf
- Jones SB, and JL Male. 2012. "Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: 2011 State of Technology and Projections to 2017. PNNL-22133, Pacific Northwest National Laboratory, Richland, WA. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22133.pdf
- Biddy MJ, A Dutta, SB Jones, and PA Meyer. 2013. "Ex-Situ Catalytic Fast Pyrolysis Technology Pathway" PNNL-22317, Pacific Northwest National Laboratory, Richland, WA http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22317.pdf
- Biddy MJ, A Dutta, SB Jones, and PA Meyer. "In-Situ Catalytic Fast Pyrolysis Technology Pathway" 2013. PNNL-22320, Pacific Northwest National Laboratory, Richland, WA http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22320.pdf
- Talmadge M, MJ Biddy, A Dutta, SB Jones, and PA Meyer. 2013. "Syngas Upgrading to Hydrocarbon Fuels Technology Pathway." PNNL-22323, Pacific Northwest National Laboratory, Richland, WA http://www.pnl.gov/main/publications/external/technical_reports/PNNL-22323.pdf

Publications & Presentations

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Publications, cont.

- Jones SB, and LJ Snowden-Swan. 2013. "Production of Gasoline and Diesel from Biomass via Fast Pyrolysis, Hydrotreating and Hydrocracking: 2012 State of Technology and Projections to 2017." PNNL-22684, Pacific Northwest National Laboratory, Richland, WA http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22684.pdf
- Jones SB, PA Meyer, LJ Snowden-Swan, AB Padmaperuma, E Tan, A Dutta, J Jacobson, and K Cafferty. 2013. "Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbon Fuels: Fast Pyrolysis and Hydrotreating Bio-Oil Pathway." PNNL-23053; NREL/TP-5100-61178, Pacific Northwest National Laboratory, Richland, WA http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23053.pdf
- Dunn, J., M. Johnson, Z. Wang, M. Wang, K. Cafferty, J. Jacobson, E Searcy, M Biddy, A Dutta, D Inman, E Tan, L Tao, S Jones, and L Snowden-Swan. Nov. 2013. Supply Chain Sustainability Analysis of Three Biofuel Pathways: Biochemical Conversion of Corn Stover to Ethanol, Indirect Gasification of Southern Pine to Ethanol, Pyrolysis of Hybrid Poplar to Hydrocarbon Fuels. ANL/ESD-14/5.
- Jones SB, LJ Snowden-Swan, PA Meyer, AH Zacher, MV Olarte, and C Drennan. 2014. Fast Pyrolysis and Hydrotreating 2013 State of Technology R&D and Projections to 2017 . PNNL-23294, Pacific Northwest National Laboratory, Richland, WA. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23294.pdf
- Zacher AH, MV Olarte, DM Santosa, DC Elliott, and SB Jones. 2014. "A Review and Perspective of Recent Bio-Oil Hydrotreating Research ." Green Chemistry 16(2):885-896.
- PNNL contributed to following publications (in press): NREL: Catalytic Pyrolysis ; NREL: Syngas Conversion; ANL Fast Pyrolysis SCSA

Publications & Presentations

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Presentations

- Zhu Y, MA Gerber, SB Jones, and DJ Stevens. 2010. "Techno-Economic Analysis of Effects of Alternative Tar-Removal Assumptions on Lignocellulosic Biomass-to-Ethanol Systems." In 2010 AIChE Spring Meeting & 6th Global Congress on Process Safety, March 21-25, 2010, San Antonio, Texas. PNNL-SA-70706, Pacific Northwest National Laboratory, Richland, WA.
- Jones SB. 2010. "Thermochemical Processing of Biomass for Fuels Production." Presented by Susanne B. Jones at Thermochemical Conversion Symposium TCS2010, Ames , IA on September 23, 2010. PNNL-SA-75364.
- Jones SB. 2011. "PNNL TC Analysis Review February 2011 DOE." Presented by Susanne B. Jones (Invited Speaker) at 2011 DOE Biomass Program Review Thermochemical Platform, Denver, CO on February 17, 2011. PNNL-SA-78106.
- Snowden-Swan LJ. 2011. "Sustainability Assessment for Biomass Thermochemical Conversion Technologies." Presented by Lesley J. Snowden-Swan (Invited Speaker) at AIChE-IfS Pacific Northwest Sustainability Conference 2011, Seattle, WA on April 30, 2011. PNNL-SA-79541.
- Jones SB, LJ Snowden-Swan, PA Meyer, A Dutta, E Tan, and SD Phillips. 2013. "Thermochemical Platform Analysis-Fast Pyrolysis Design Case and Sustainability Interface 3.6.1.1, 3.6.1.3, 3.1.2.4." Presented by Susanne Jones, Lesley Snowden-Swan and Abhijit Dutta at Bioenergy Technologies Office, Alexandria, VA on May 21, 2013. PNNL-SA-95360.
- Jones SB, Y Zhu, A Dutta, E Tan, and SD Phillips. 2013. "Thermochemical Platform Analysis-Hydrothermal Liquefaction Techno-Economics 3.6.1.1, 3.6.1.3 (Non-scored)." Presented by Susanne Jones (Invited Speaker) at Bioenergy Technologies Office 2013 Project Peer Review, Alexandria, VA on May 23, 2013. PNNL-SA-95416.

Publications & Presentations

Presentations, cont.

- Snowden-Swan LJ, SB Jones, JL Male and P Meyer. Life Cycle Greenhouse Gas Emissions of Biofuel from Fast Pyrolysis and Bio-Oil Upgrading. Poster presentation at the ACLCA LCA XII Conference, Tacoma, WA, September 25-27, 2012.
- S Jones, L Snowden-Swan, P Meyer. “Bio-Oil Upgrading Economics and Sustainability”, presented at the Thermochemical Workshop, University of Delaware, October 8, 2013
- Olarte MV, AH Zacher, SB Jones, LJ Snowden-Swan, PA Meyer, AB Padmaperuma, LJ Rotness, Jr, GG Neuenschwander, DC Elliott, and C Drennan. 2014. "Current State of the Technology (SOT) of the Fast Pyrolysis-Hydrotreating Pathway." Presented by Mariefel V. Olarte at Biomass 2014, Washington DC, DC on July 29, 2014. PNNL-SA-104180

Abbreviations and Acronyms

- ANL Argonne National Laboratory
- AOP: annual operating plan
- BETO: Bioenergy Technologies Office
- GGE: gasoline gallon equivalent
- INL: Idaho National Laboratory
- LCA: life-cycle analysis
- MFSP: minimum fuel selling price
- MYPP: multi-year program plan
- NPV: net present value
- PMP: project management plan
- PNNL: Pacific Northwest National Laboratory
- TEA: techno-economic analysis