U.S. Department of Energy (DOE)
Bioenergy Technologies Office (BETO)
2019 Project Peer Review

1.1.1.2 Feedstock Supply Chain Analysis

March 7, 2019
Feedstock Logistics

This presentation does not contain any proprietary, confidential, or otherwise restricted information.
Goal Statement

Goals

• Leading-edge feedstock analyses that
  – Track programmatic progress towards BETO programmatic goals
  – Identify R&D technology performance and cost targets that achieve program goals
  – Provide programmatic verification so that goals are achieved

Outcomes

• Supply system $n$th-plant TEAs that guide the direction of technology development
• Leading-edge analyses that inform industry of the potential for BETO-funded technologies to positively impact process economics and reliability

Relevance to the bioenergy industry

• Evaluate tradeoffs & interdependencies among modeled cost, quality, resource availability, sustainability, risk, technology advances, and logistics improvements
• TEAs assess cost-competitive routes to incorporate distributed, and variable quality, biomass resources into bioenergy feedstocks, as well as the potential $n$th-plant supply system cost impacts of BETO-funded technology improvements
Quad Chart Overview

Timeline
- Project start date: 10/1/2005
- Project end date: NA
- This project is foundational to the BETO FSL portfolio and is an ongoing project

<table>
<thead>
<tr>
<th></th>
<th>Total Costs Pre FY17</th>
<th>FY 17 Costs</th>
<th>FY 18 Costs</th>
<th>Total Planned Funding (FY 19-Project End Date)</th>
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</thead>
<tbody>
<tr>
<td><strong>DOE Funded</strong></td>
<td>$2.960M</td>
<td>$882.1K</td>
<td>$849.6K</td>
<td>$2.004M</td>
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<td><strong>Project Cost Share</strong></td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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</tbody>
</table>

Barriers addressed
- Ft-A. Terrestrial Feedstock Availability and Cost
- Ft-I. Overall Integration and Scale-Up

Objective
- Deliver leading-edge feedstock analyses that identify R&D technology performance, quality and cost targets to achieve BETO goals, track progress toward the goals, & verify the goals were achieved.

End of Project Goals
- Track progress toward the $3/gge BETO 2022 cost target (2016$) for the four conversion processes represented in the 2018 BETO MYPP (IDL, CFP, BC, AHTL). Technology progress for feedstock supply to each of these conversion processes will be individually tracked toward their pathway-specific delivered 2022 feedstock cost targets, including $63.76/dry ton for IDL, $70.31/dry ton for CFP, $79.07/dry ton for BC, and $70.35/dry ton for AHTL (all in 2016$).

Partners/Collaborators:
- Collaborators include all FSL R&D AOP Projects, industry projects (data source), and other BETO National Laboratories performing TEA and LCA.
1 – Project Overview

CONTEXT/HISTORY

• FY12 Design: Conventional supply system in high-yielding region
• FY13 Design: Conventional supply system in lower-yielding but more diverse region
• FY14-16: Progress tracking to 2017 Design
• FY17/18 Design: Advanced supply system incorporating decoupling from the biorefinery, blended, conversion-ready feedstocks, active quality management & densified, flowable format

OBJECTIVES

• Demonstrate how BETO-funded R&D collectively contributed to achieving the FY17 $85.51/ton modeled cost target (2016$)
• Demonstrate how BETO-funded R&D collectively contributed to modeled cost reductions of at least $65/ton and $24/ton relative to the 2013 TEAs of biochemical and thermochemical pathways, respectively (2016$)
• Significantly expand beyond feedstock cost metrics to include reliability and risk

CREATIVE ADVANTAGE

• Beyond cost, our integrated analyses account for resource availability, logistical improvements, technological advances and environmental performance
• Previously unaccounted for costs and interdependencies are captured by developing new and innovative approaches and computational capabilities to model supply systems
2 – Approach (Management)

- **Data collection and alignment** through BETO feedstock R&D projects and industry outreach
- **Engage stakeholders** to clarify potential versus actual barriers to mobilizing biomass and discuss potential approaches for addressing the barriers
- **Collaborate** to include results across BETO platforms (e.g., BT16, BSM)
- **Bi-weekly conference calls** with BETO
- **Bi-weekly coordination calls** with ORNL
- **5-7 milestones per year**
  - Quarterly Progress milestones
  - SMART Annual Milestones for high-impact deliverables and outcomes
- **Team Structure**
  - **SOTs & Design Cases:** Damon Hartley (woody), Mohammad Roni (herbaceous)
  - **New Capabilities Development:** Jason Hansen, Mike Griffel, Damon Hartley, Ross Hays, Hongqiang Hu, Shyam Nair, Quang Nguyen, Mohammad Roni

*Enlarged grapple arms for the Tigercat wheeled skidder design developed through the DOE-funded Auburn University High-Tonnage Logistics Project*
TECHNICAL APPROACH

• Develop design reports and projections to identify specific technical targets to achieve cost targets
• Track annual progress toward BETO cost and technical targets established in the design report (SOT reports)
• Identify advanced systems that can mobilize resources and overcome problems identified by the pioneer biorefineries by looking beyond the current nth-plant designs
• Develop new computational capabilities where necessary to expand analysis to answer new questions

TOP 3 TECHNICAL CHALLENGES

• Existing paradigms related to feedstock supply (i.e., cheap vs. reliable)
• Credibly modeling costs that are not yet recognized as costs
• Lack of complete datasets for harvest, composition, preprocessing and convertibility, across multiple biomass resources

Source: http://www.flickr.com/photos/mollivan_jon/3439072283/
CRITICAL SUCCESS FACTORS

• Technical
  – Design reports with plausible pathways to meeting nth-plant targets
  – Integrated analyses that account for cost, quality, resource availability, logistical improvements, technological advancements, environmental performance and risk
  – Supply system designs that provide value across the supply chain to support market development

• Business
  – Effective dissemination of vision and results for conversion-ready engineered (advanced) feedstock supply systems

IMPORTANCE OF GO/NO-GO DECISION POINTS

• For this project, Go/No-go Decision Points guide the selection of new and advanced approaches for mobilizing the large fraction of the billion tons of biomass that are potentially available but unsuitable for use as bioenergy feedstocks
• Compare costs of conventional (existing) supply systems with these advanced approaches
• Example: Determination of advanced feedstock supply systems as a viable option for meeting BETO cost, volume and quality targets
  – Identify and quantify the attributes of an AFSS that outperform CFSS based on supply system metrics including cost, reliability, quality, risk, etc.
  – Go: Identify at least one attribute of AFSS and quantitatively identify how it outperforms CFSS.
### 3 – Technical Accomplishments

**N\textsuperscript{th}-PLANT DESIGNS & PROJECTIONS →**

**Example: 2022 HERBACEOUS CASE**

#### EXAMPLE

**2022 Herbaceous Projection for BC Platform**

<table>
<thead>
<tr>
<th>Year</th>
<th>2013 SOT</th>
<th>2017 SOT</th>
<th>2018 SOT</th>
<th>2022 Projection</th>
<th>2030 Projection</th>
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<tbody>
<tr>
<td>Cost</td>
<td>$40.61</td>
<td>$46.66</td>
<td>$20.52</td>
<td>$13.43</td>
<td>$16.91</td>
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<tr>
<td></td>
<td>$23.24</td>
<td>$22.49</td>
<td>$16.91</td>
<td>$12.79</td>
<td>$22.37</td>
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<tr>
<td></td>
<td>$16.91</td>
<td>$13.43</td>
<td>$16.45</td>
<td>$8.35</td>
<td>$71.26</td>
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#### Sensitivity Analysis

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Change in delivered cost relative to Base Case</th>
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<tbody>
<tr>
<td>Hammer mill throughput</td>
<td>-$1.80</td>
</tr>
<tr>
<td>Baling rate</td>
<td>-$1.12</td>
</tr>
<tr>
<td>Bale density</td>
<td>-$0.32</td>
</tr>
<tr>
<td>Storage dry matter loss</td>
<td>-$0.90</td>
</tr>
<tr>
<td>Bale processor throughput</td>
<td>-$0.10</td>
</tr>
<tr>
<td>Hammer mill energy consumption</td>
<td>-$0.21</td>
</tr>
<tr>
<td>Pelleting energy consumption</td>
<td>-$0.16</td>
</tr>
<tr>
<td>Windrow rate</td>
<td>-$0.09</td>
</tr>
<tr>
<td>Bale processor energy consumption</td>
<td>-$0.07</td>
</tr>
<tr>
<td>Pelleting throughput</td>
<td>-$0.07</td>
</tr>
<tr>
<td>Bypass during fractional milling</td>
<td>-$0.07</td>
</tr>
<tr>
<td>Baler transport loading/unloading time</td>
<td>-$0.07</td>
</tr>
<tr>
<td>Rotary shear throughput</td>
<td>-$0.07</td>
</tr>
<tr>
<td>Rotary shear energy consumption</td>
<td>-$0.07</td>
</tr>
</tbody>
</table>

#### 2017 Blend: 12.15% 3-pass corn stover, 75.72% 2-pass stover, 8.23% switchgrass, 3.91% grass clippings

#### 2018 Blend: 12.74% 3-pass corn stover, 73.22% 2-pass stover, 9.83% switchgrass, 4.21% grass clippings

#### 2022 Blend: 49.95% 3-pass corn stover, 12.23% 2-pass stover, 33.03% switchgrass, 4.79% grass clippings
3 – Technical Accomplishments (continued)

**SOT TRACKING ➔ DELIVERED COST IMPACTS**

**ACCOMPLISHMENT**

- Achieved the 2017 $85.51/dry ton (2016$) $n^{th}$-plant feedstock cost target (MYPP FSL Milestone)
- FY13-17 R&D accomplishments resulted in a 45% reduction in delivered herbaceous feedstock cost ($83.90/dry ton)

**IMPACT**

- Cost of pellet production (~$7/ton) is now lower than the FY13 SOT cost of grinding alone
- Least-cost formulation and blending significantly improved feedstock quality, nearly eliminating quality dockage
- First documented analysis of depot cost benefit

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### Biomass Type Summary

<table>
<thead>
<tr>
<th>Biomass Type</th>
<th>Raw Biomass Purchased (dry tons)</th>
<th>Pelleted Blendstocks Produced (dry tons)</th>
<th>Pelleted Blendstocks</th>
<th>Delivered Cost ($/dry ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total Carbohydrates (wt% db)</td>
<td>Ash (wt% db)</td>
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<tr>
<td>Three-pass corn stover</td>
<td>112,686</td>
<td>57.40%</td>
<td>12.20%</td>
<td>$83.82</td>
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<tr>
<td>Two-pass corn stover</td>
<td>702,366</td>
<td>60.30%</td>
<td>7.60%</td>
<td>$84.53</td>
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<tr>
<td>Switchgrass</td>
<td>73,017</td>
<td>66.60%</td>
<td>6.40%</td>
<td>$89.91</td>
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<tr>
<td>Grass clippings</td>
<td>32,069</td>
<td>28.70%</td>
<td>13.10%</td>
<td>$59.38</td>
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<tr>
<td>Totals</td>
<td>920,138</td>
<td>59.23%</td>
<td>8.28%</td>
<td>$83.90</td>
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</table>
### Cost Trade-Offs Among Supply System Operations

- All costs shown in 2016$, for nth-plant supply scenario in western KS

<table>
<thead>
<tr>
<th></th>
<th>2013 SOT</th>
<th>2017 SOT</th>
<th>% Difference</th>
<th>Explanation</th>
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</thead>
<tbody>
<tr>
<td>Grower payment</td>
<td>$40.61</td>
<td>$23.24</td>
<td>-43%</td>
<td>Least-cost formulation/blending &amp; use of depots (supply curves)</td>
</tr>
<tr>
<td>Harvest and collection</td>
<td>$20.52</td>
<td>$16.91</td>
<td>-18%</td>
<td>Least-cost formulation/blending</td>
</tr>
<tr>
<td>Storage and queuing</td>
<td>$4.60</td>
<td>$6.54</td>
<td>+42%</td>
<td>Increase due to additional storage requirement</td>
</tr>
<tr>
<td>Transportation and handling</td>
<td>$15.49</td>
<td>$13.43</td>
<td>-13%</td>
<td>Depots/densification</td>
</tr>
<tr>
<td>In-plant receiving and preprocessing</td>
<td>$46.60</td>
<td>$22.52</td>
<td>-52%</td>
<td>Rotary shear, fractional milling &amp; high-moisture densification</td>
</tr>
<tr>
<td>Dockage</td>
<td>$21.49</td>
<td>$1.27</td>
<td>-94%</td>
<td>Least-cost formulation/blending</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$149.31</td>
<td>$83.90</td>
<td>-44%</td>
<td></td>
</tr>
</tbody>
</table>

- Delivered cost is $1.61/dry ton lower than the BETO target of $85.51/dry ton (2016$)
- Depot preprocessing ($83.90/dry ton) similar to centralized preprocessing ($84.21/dry ton)
- Utilizing depots allows access to more feedstock on the lower end of the supply curve
3 – Technical Accomplishments (continued)

NEW AND EXPANDED COMPUTATIONAL CAPABILITIES

- Biomass Logistics Model historically provided only cost analyses
- New state-of-the-art tools/add-ins developed to provide advanced analysis

<table>
<thead>
<tr>
<th>New Model</th>
<th>New Capability</th>
</tr>
</thead>
</table>
| Biomass Logistics Model Update   | • Improves maintainability and ease of use  
• Handles blending of feedstocks internally  
• Tracks and accounts for multiple product streams |
| Expansion of the least-cost formulation model | • Optimally sites & scales local distributed preprocessing depots as a variable in the determination of the least-cost blend  
• Identifies feedstock cost reduction opportunities utilizing additional biomass resources from integrated landscape management |
| Biorefinery Supply Assessment Model | • Determines biorefinery gate cost of biomass based on biorefinery size and specified average delivered cost  
• Both national- and regional-level assessment of accessible biomass rather than for predetermined supply sheds |
| Operational Reliability Model    | • Simulates the impact of feedstock properties on preprocessing system productivity  
• Quantify the cascading effects of processing upsets through a preprocessing system |
EXPANDED LEAST-COST FORMULATION MODEL

ANALYSIS ACCOMPLISHMENT
- Only specifies biorefinery location, available feedstocks & supply curves
- Determines optimal number, size and location of depots
- Applies dockage as a variable
- Minimizes delivered cost while meeting carbohydrate & size specs

IMPACT
- Enables dynamic blending to specs
- Optimal solution can utilize lower quality cost-advantaged feedstocks
- Allows taking dockage rather than higher cost

<table>
<thead>
<tr>
<th>Node</th>
<th>Identifier</th>
<th>County</th>
<th>Capacity (dry tons/yr)</th>
<th>Biomass Type</th>
<th>Biomass Source Nodes</th>
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<tbody>
<tr>
<td>-</td>
<td>Biorefinery</td>
<td>Sheridan, KS</td>
<td>800,000</td>
<td>Blend</td>
<td>4, 6, 12, 14</td>
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<tr>
<td>4</td>
<td>Depot</td>
<td>Harlan, NE</td>
<td>400,000</td>
<td>two-pass corn stover</td>
<td>2, 3, 4, 7</td>
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<td>6</td>
<td>Depot</td>
<td>Furnas, NE</td>
<td>360,000</td>
<td>three-pass corn stover</td>
<td>6</td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td>two-pass corn stover</td>
<td>2, 5, 8</td>
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<tr>
<td>12</td>
<td>Depot</td>
<td>Graham, KS</td>
<td>80,000</td>
<td>three-pass corn stover</td>
<td>1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>switchgrass</td>
<td>9, 10, 11, 12, 13</td>
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<tr>
<td>14</td>
<td>Depot</td>
<td>Denver, CO</td>
<td>32,000</td>
<td>grass clippings</td>
<td>Denver metropolitan area</td>
</tr>
</tbody>
</table>
ANALYSIS ACCOMPLISHMENT

- Used to address IBR operability
- Identified moisture and fines as the primary drivers of preprocessing downtime
- Achieved only 27% of design throughput with 4 preprocessing lines
- Maximum throughput of 45%, required 94 preprocessing lines

IMPACT

- Results were consistent with the findings of the DOE Tiger team
- Contributed to the R&D approach established for the Feedstock-Conversion Interface Consortium (FCIC)
3 – Technical Accomplishments (continued)

OPERATIONAL RELIABILITY MODEL – *What-if Analysis*

**ANALYSIS ACCOMPLISHMENT**

- Analysis for NREL-SI (BSM)
- Shows 90% uptime is possible with 11 preprocessing lines by managing the inputs to preprocessing and pretreatment
- Required rejecting 300K tons of bales and 800K tons of fines in order to deliver 720K tons of corn stover to pretreatment

**IMPACT**

- Illustrates that conventional systems can achieve 90% uptime
- Shows that the rejected biomass cannot be simply discarded
- Indicates need for both quality management and improved technology
3 – Technical Accomplishments (continued)

BIOREFINERY SUPPLY ASSESSMENT MODEL

ANALYSIS ACCOMPLISHMENT

- Shows the trade-off between biomass supply and biorefinery scale
  - Maximum supply available for the smallest biorefinery
  - At the largest scale, biomass supply is limited to higher tier of cost
- Regional supply is highly segmented

IMPACT

- Enables national and regional resource utilization under optimal biorefinery gate cost scenarios
- Prerequisite to cost/quality assessments toward attainment of BETO cost and volume targets

(e.g. Pine Logging Residues)

NATIONAL ANALYSIS

REGIONAL ANALYSIS

<table>
<thead>
<tr>
<th>Region</th>
<th>200,000 dt capacity</th>
<th>400,000 dt capacity</th>
<th>600,000 dt capacity</th>
<th>800,000 dt capacity</th>
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<tbody>
<tr>
<td></td>
<td>$26/dt</td>
<td>$32/ht</td>
<td>$38/ht</td>
<td>$26/ht</td>
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<tr>
<td>Mountain</td>
<td>0</td>
<td>269,036.2</td>
<td>265,899.9</td>
<td>0</td>
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<tr>
<td>Northern Plains</td>
<td>0</td>
<td>101,509.9</td>
<td>106,470.9</td>
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<tr>
<td>Southern Plains</td>
<td>143,746.3</td>
<td>212,992.6</td>
<td>220,770.1</td>
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<td>Heartland</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Northeastern</td>
<td>250.8</td>
<td>192.28</td>
<td>652,260.9</td>
<td>0</td>
</tr>
<tr>
<td>Southern</td>
<td>75,946.7</td>
<td>95,206.1</td>
<td>95,250.2</td>
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</tr>
<tr>
<td>Pacific</td>
<td>286,010.4</td>
<td>371,076.9</td>
<td>223,277.4</td>
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<tr>
<td>Northwest</td>
<td>545,254.8</td>
<td>111,370.3</td>
<td>114,085.5</td>
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<tr>
<td>Delta</td>
<td>452,987.9</td>
<td>583,061.5</td>
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<td>Eastern Mountain</td>
<td>145,364.5</td>
<td>380,742.5</td>
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<td>Upper Midwest</td>
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<td>Great Lakes</td>
<td>286,625</td>
<td>601,538</td>
<td>532,389.5</td>
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</table>
3 – Technical Accomplishments (continued)

SIGNIFICANT DELIVERABLES

FY17
• 2017 Woody SOT (1 pathway)
• 2017 Herbaceous SOT (1 pathway)
• Go/No-go Report: Determination of advanced feedstock supply systems as a viable option for meeting BETO cost, volume, and quality targets

FY18
• 2018 Woody SOTs with 2022 Projections (3 pathways)
• 2018 Herbaceous SOT with 2022 Projection (1 pathway)

FY19 Q1
• National-scale cost/volume models for delivery of 3-pass corn stover, 2-pass corn stover and switchgrass to the biorefinery gate for a range of biorefinery sizes, costs and quality specifications

State of Technology reports (SOTs) directly support multiple terrestrial feedstock conversion TEAs
4 – Relevance

PRODUCTS AND OUTPUTS

• Credible, objective analyses of feedstock supply systems and strategies to support BETO investments
• Potential solutions and data regarding cost effective feedstock supply to existing pioneer biorefineries
• Annual SOT reports that track R&D progress toward BETO programmatic goals and targets

CUSTOMERS

• DOE is the primary customer, but other federal agencies, the bioenergy industry, and university partners are potential beneficiaries

Conventional supply systems (CFSS) provide biomass to existing markets that have less stringent quality requirements than biorefineries do. They are vertically integrated supply systems, designed around:

• Limited markets
• Single biomass type
• Single conversion facility
• Limited supply radius
INTENDED USE BY CUSTOMERS

• BETO – Gauge progress of feedstock supply system improvements to mobilize biomass
• BETO and Labs – Assessment of potential technology solutions to feedstock supply and quality barriers to expanding the bioenergy industry

INDUSTRY ENGAGEMENT

• Data collection related to harvest, transportation, storage and preprocessing
• Cost-impact analyses to better understand cost-effective solutions to pioneer biorefinery operational issues related to biomass properties

An AFSS dynamically provides a “conversion-ready” engineered feedstock from a myriad of diverse raw biomass sources, and decouples the supply of this engineered feedstock from the biorefinery infeed. “Conversion-ready” implies that the engineered feedstock meets all quality specifications for the specific conversion process.
5 – Future Work

PLANS THROUGH FY21 (AND BEYOND)

- State of Technology analysis and reporting for the four MYP Platforms (BC, IDL, CFP, AHTL)
- Design Case development for reaching MYP target of 90% operational reliability
- Advanced Feedstock Supply System definition and analysis
  - Develop nth-plant supply curve assumptions for feedstock supply (collaborative with ORNL)
  - Develop cost-scale and cost-quality relationships for industrially-relevant biomass sources to support MYPP cost targets of $3.00/gge in 2022 and $2.50/gge in 2030

Table 1 Regional Quantities Delivered by Price and Refinery Size

<table>
<thead>
<tr>
<th>Region</th>
<th>200,000 dt capacity</th>
<th>400,000 dt capacity</th>
<th>600000 dt capacity</th>
<th>800000 dt capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountain</td>
<td>$56/dt</td>
<td>$74/dt</td>
<td>$80/dt</td>
<td>$56/dt</td>
</tr>
<tr>
<td></td>
<td>24413.91</td>
<td>71816.1</td>
<td>79156</td>
<td>0</td>
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<td></td>
<td>483163</td>
<td>724071</td>
<td>91821.2</td>
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<td>$56/dt</td>
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National Analysis – 3-pass Corn Stover
5 – Future Work (continued)

UPCOMING KEY MILESTONE

• September 30, 2019: Deliver annual State of Technology designs for the biochemical and thermochemical design cases that detail feedstock R&D progress. Track progress toward the $3/gge BETO 2022 cost target (2016$) for the four conversion processes represented in the 2018 BETO MYP (IDL, CFP, BC, AHTL). Technology progress for feedstock supply to each of these conversion processes will be individually tracked toward their pathway-specific delivered 2022 feedstock cost targets, including $63.76/dry ton for IDL, $70.31/dry ton for CFP, $79.07/dry ton for BC, and $70.35/dry ton for AHTL (all in 2016$).
  – State of Technology (SOT) reports will be delivered that include analyses of field to reactor throat logistics and preprocessing for feedstock supply to each of these pathways.

GO/NO-GO DECISION POINT

• March 31, 2019: Quantify 3-pass corn stover, 2-pass corn stover and switchgrass volumes meeting quality specs available to supply at least 5 biorefineries at the 2022 MFSP target of $3/gge.
  – Description: This analysis assesses, at national and regional scales, the reactor-throat delivered cost for industrially relevant herbaceous feedstocks to meet a range of quality specifications delivered to the 2030 design biochemical conversion process, over a range of biorefinery sizes. This information will be critical to understand the required quantities and qualities of potential candidates for economically advantaged feedstocks for supply to biochemical conversion.
Summary

KEY TAKEAWAYS

OVERVIEW: We are guiding feedstock mobilization research toward AFSS that incorporate decoupling from the biorefinery with blended, conversion-ready feedstocks

APPROACH: Engaging stakeholders, we develop innovative solutions to existing and future supply mobilization barriers, while informing BETO to guide R&D direction

ACCOMPLISHMENTS: Annual SOT tracking, new computational capabilities, analysis successfully predicted pioneer biorefinery operational issues

RELEVANCE: Foundational support to BETO guiding feedstock mobilization research, annual SOT reports tracking R&D progress, assessment of potential technology solutions to feedstock supply and quality barriers to expanding the bioenergy industry

FUTURE WORK: Pioneer biorefinery lessons learned have guided us toward quantifying the costs of operational reliability and supply risks in both CFSS and AFSS
Questions?

Source: http://karenshulman.com/portfolio-view/running-effective-meetings/
Additional Slides
2017 PEER REVIEW COMMENT

• “The results presented can be criticized on several points. The analyses seem to indicate that BETO is being successful in meeting cost targets for delivered biomass, but the industry reality is that such targets are not being met. Are the modeled assumptions being too optimistic?”

FY17-18 ACTIONS TAKEN IN RESPONSE TO COMMENT

• In line with the conversion TEAs, our design cases and SOTs present n^{th}-plant scenarios that assume that all of the operational issues have been overcome, rather than the 1st-plant scenarios experienced by the pioneer biorefineries.

• We developed the Operational Reliability Model and used it to show that feedstock moisture entering preprocessing led to operational difficulties and failures due to excess fines generation entering pretreatment, a result that was reflected in pioneer biorefinery operational information gathered by the DOE Tiger Team.
2017 PEER REVIEW COMMENT

“The data presented gave only single value estimates at each point in time. What about including variance on the SOT estimates? Adding uncertainty to each of the number used in the analysis will certainly complicate the analysis, but would provide a better understanding of the real confidence in the estimates.”

FY17-18 ACTIONS TAKEN IN RESPONSE TO COMMENT

• Unfortunately, while possible in the Biomass Logistics Model, Monte Carlo analyses are unwieldy and difficult to complete in the current BLM framework.

• To alleviate this limitation, we built Aspen Plus modules for the preprocessing operations to allow the sensitivity analysis to be done more easily.

• Additionally, we migrated the BLM from PowerSim to basic code in Python language to allow more varied and faster sensitivity analysis.

• Sensitivity analyses were completed for all SOTs and Projections.
Highlights from FY17 Go/No-go Decision Point

FY17 GO/NO-GO DECISION POINT (March 31, 2017)

• Based on a quantitative analysis, identify and quantify the attributes of an AFSS that outperforms CFSS based on supply system metrics including cost, reliability, quality, risk, etc.

• Go: Identify at least one attribute of AFSS such as decoupled feedstock supply, increased density, improved stability, and conversion readiness, and quantitatively identify how it outperforms CFSS.

DECISION: GO

• We utilized Discrete Event Simulation to model the operational reliability of preprocessing and feeding to the pretreatment reactor.

• Data sources
  – INL Bioenergy Feedstock Library data & INL Preprocessing PDU performance data
  – Feedstock property-caused failure/downtime information derived from pioneer biorefinery operational experience

• Feedstock moisture entering preprocessing and failures of the compression screw feeder due to excessive fines were shown to be the dominant factors leading to unreliable operation of preprocessing and feeding.

• Modeled capacity utilization was 27% of design, which was very similar to the pioneer biorefinery operational information gathered by the DOE Tiger Team.

• AFSS that reduced moisture and reduced fines were shown to be capable of reaching a maximum 45% capacity utilization; total fines elimination would result in 90% maximum utilization.
PUBLICATIONS


PUBLICATIONS SUPPORTED BY ANALYSIS FROM THIS PROJECT


Supporting Slides
SENSITIVITY ANALYSIS 2022 HERBACEOUS PROJECTION

- Hammer mill throughput (odt/hr) [3P-CS, 2P-CS]: 2.93, 4.00, 4.47; SG: 4.37, 5.00, 5.56; GC: 4.63, 5.50, 6.12
- Baling rate (odt/hr) [3P-CS: 16.14, 26.18, 28.10; 2P-CS: 11.7, 19.00, 28.10; SG: 24.04, 27.36, 28.10]
- Bale density (lb/ft^3) [3P-CS, 2P-CS: 11, 12, 13; SG: 9, 12, 13]
- Storage dry matter loss (%) [3P-CS, 2P-CS: 5, 7, 12; SG: 4, 7, 12]
- Bale processor throughput (odt/hr) [3P-CS, 2P-CS, SG: 4, 5, 6]

Conservation:
- Hammer mill energy consumption (kWh/odt) [3P-CS, 2P-CS: 5.77, 9.00, 11.17; SG: 11.81, 14.00, 18.65; GC: 3.31, 3.92, 5.22]
- Pelleting energy consumption (kWh/odt) [3P-CS, 2P-CS: 31.36, 32.62, 33.48; SG: 57.90, 60.20, 61.80; GC: 78.8, 82.0, 84.2]
- Windrowing rate (acres/hr) [3P-CS: 10.78, 11.50, 12.51; SG: 8.25, 8.8, 9.57]
- Bale processor energy consumption (hp) [3P-CS, 2P-CS, SG: 60, 75, 90]

Conservation:
- Pelleting throughput (kWh/odt) [3P-CS, 2P-CS: 3.57, 3.72, 9.12; SG: 3.32, 3.50, 3.63; GC: 3.8, 4.00, 4.18]
- Bypass during fractional milling (%) [3P-CS, 2P-CS: 35.01, 40.39, 44.00; SG: 38.50, 44.98, 46.00]
- Baler transport loading/unloading time (minutes) [3P-CS, 2P-CS, SG: 39, 42, 45]
- Rotary shear effective throughput (odt/hr) [3P-CS, 2P-CS: 11.95, 12.56, 13.21; SG: 12.95, 13.60, 14.31]
- Rotary shear effective energy consumption (kWh/odt) [3P-CS, 2P-CS: 8.26, 8.69, 9.12; SG: 1.43, 1.50, 1.58]
3 – Technical Accomplishments (continued)

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Target = $85.51
SOT TRACKING ➔ SYSTEM TECHNOLOGY TRADE-OFFS

R&D ACCOMPLISHMENTS

- Second-stage hammer mill replaced with rotary shear
- Improvements from high moisture pelleting verified with pilot-scale testing
- Inventory management in storage enables removal of cross flow grain dryer

ANALYSIS IMPACTS

- $8.02 cost reduction in biomass preprocessing
- 27.51 kg CO$_2$e/ton GHG emission reduction for in-plant receiving and biomass preprocessing