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

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

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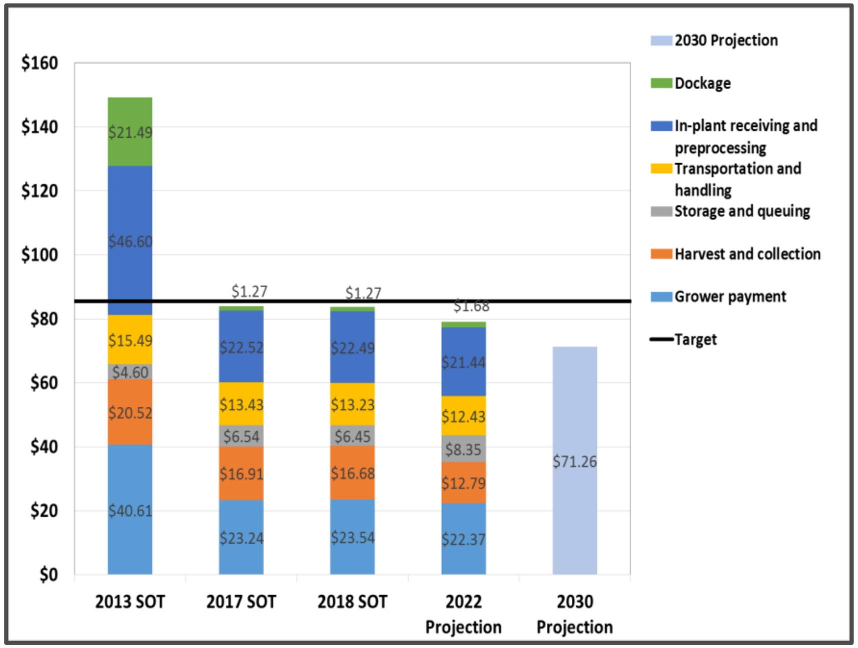
Goal Statement



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 nth-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 nth-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

	Total Costs Pre FY17	FY 17 Costs	FY 18 Costs	Total Planned Funding (FY 19-Project End Date)
DOE Funded	$2.960M	$882.1K	$849.6K	$2.004M
Project Cost Share	NA	NA	NA	NA

Partners/Collaborators:

- Collaborators include all FSL R&D AOP Projects, industry projects (data source), and other BETO National Laboratories performing TEA and LCA.

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.

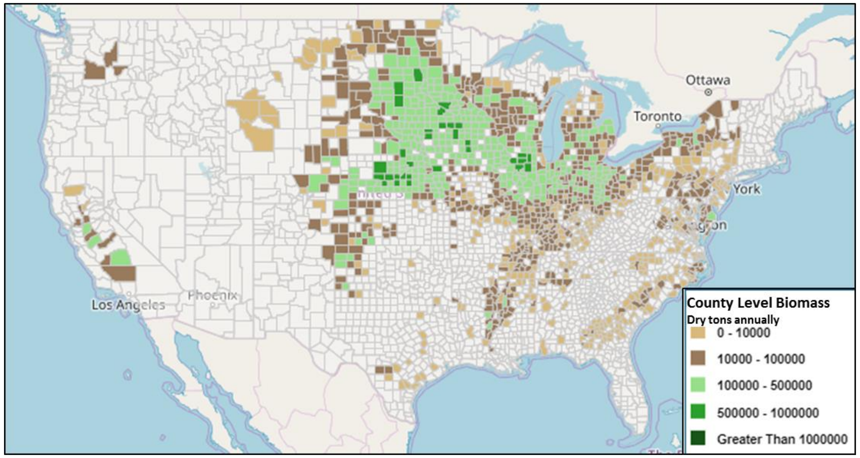
End of Project Goals

- 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 $70.35/dry ton for AHTL (all in 2016$).

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



Projected county-level corn stover availability in 2022 (BT-16 data, figure generated on the BETO KDF)

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

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2 – Approach (Technical)

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 n^{th}-plant designs
- Develop new computational capabilities where necessary to expand analysis to answer new questions

Source: http://www.flickr.com/photos/mollivan_jon/3439072283/

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

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2 – Approach (Technical) (continued)

CRITICAL SUCCESS FACTORS

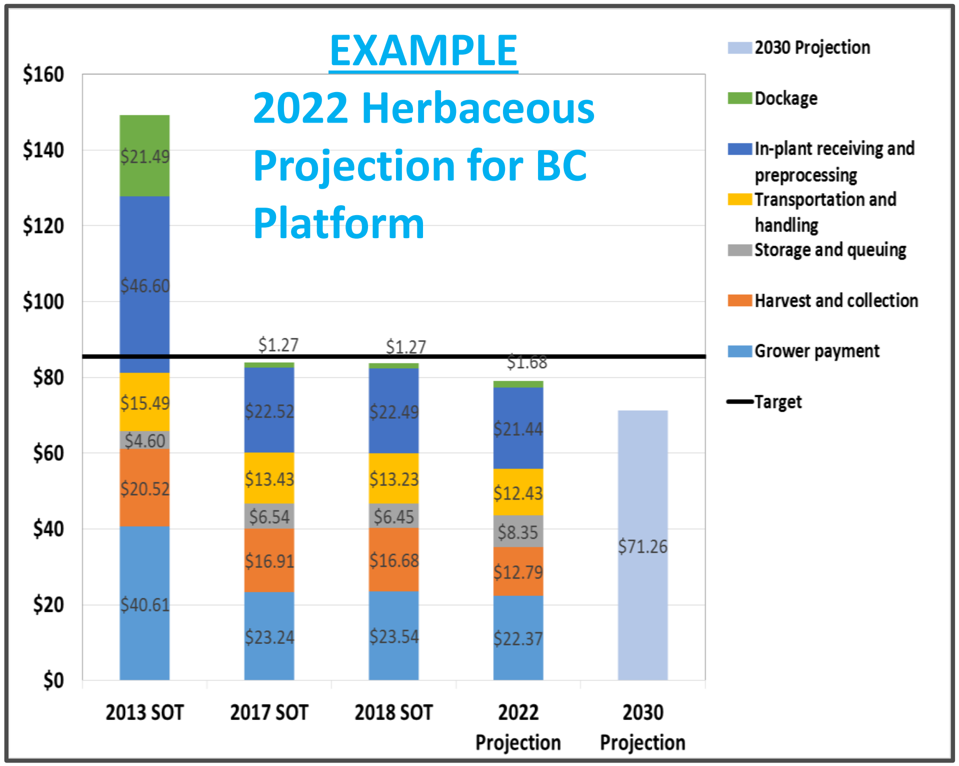
- Technical
  - Design reports with plausible pathways to meeting nth-plant targets
  - Integrated analyses that account for cost, quality, resource availability, logistical improvements, technological advancements, environmental performance and risk
  - Supply system designs that provide value across the supply chain to support market development
- Business
  - Effective dissemination of vision and results for conversion-ready engineered (advanced) feedstock supply systems

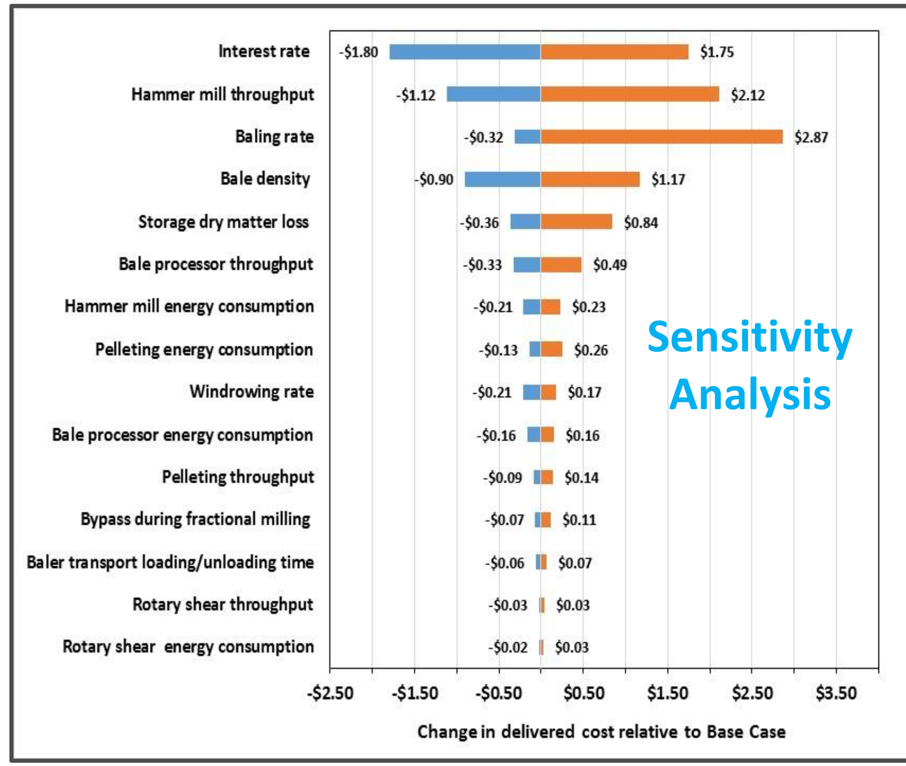
IMPORTANCE OF GO/NO-GO DECISION POINTS

- 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

Nth-PLANT DESIGNS & PROJECTIONS → Example: *2022 HERBACEOUS CASE*





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)

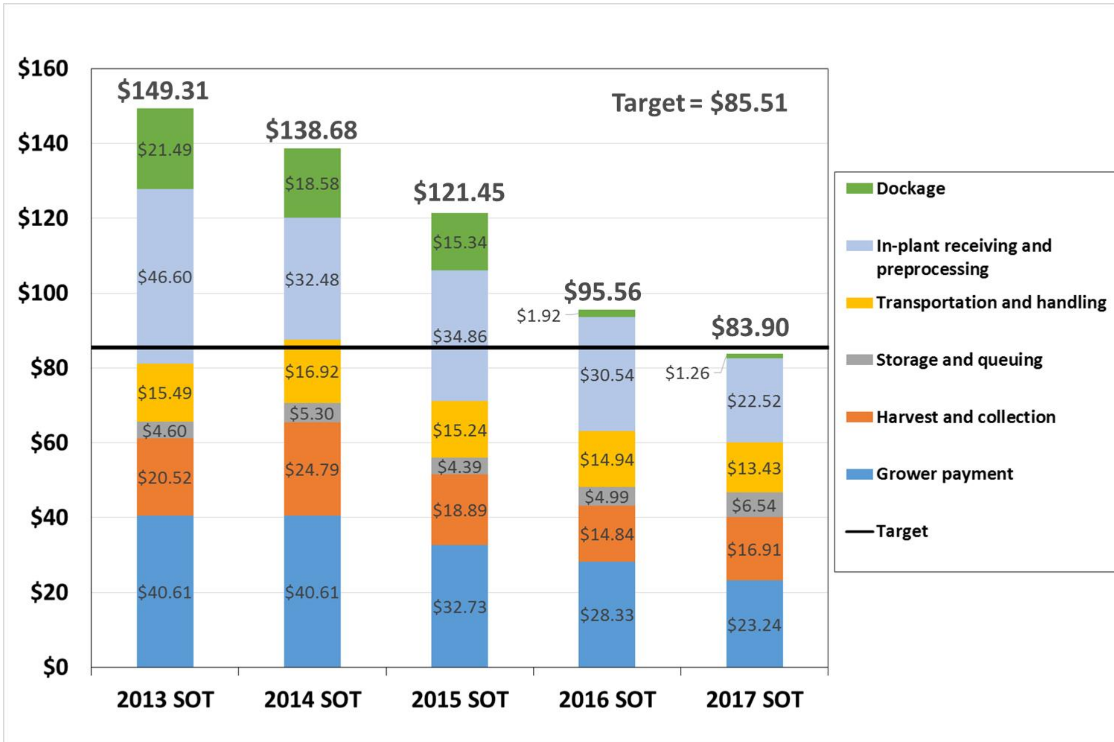
SOT TRACKING → *DELIVERED COST IMPACTS*

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



Biomass Type	Raw Biomass Purchased (dry tons)	Pelleted Blendstocks Produced (dry tons)	Pelleted Blendstocks		
			Total Carbohydrates (wt% db)	Ash (wt% db)	Delivered Cost ($/dry ton)
Three-pass corn stover	112,686	97,181	57.40%	12.20%	$83.82
Two-pass corn stover	702,366	605,720	60.30%	7.60%	$84.53
Switchgrass	73,017	65,832	66.60%	6.40%	$89.91
Grass clippings	32,069	31,267	28.70%	13.10%	$59.38
Totals	920,138	800,000	59.23%	8.28%	$83.90

3 – Technical Accomplishments (continued)

COST TRADE-OFFS AMONG SUPPLY SYSTEM OPERATIONS

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

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

- 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*

New Model	New Capability
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

3 – Technical Accomplishments (continued)

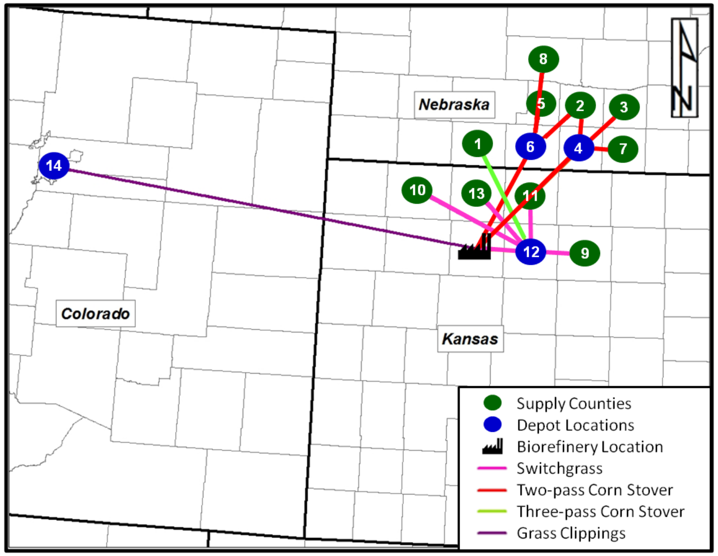
EXPANDED LEAST-COST FORMULATION MODEL

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

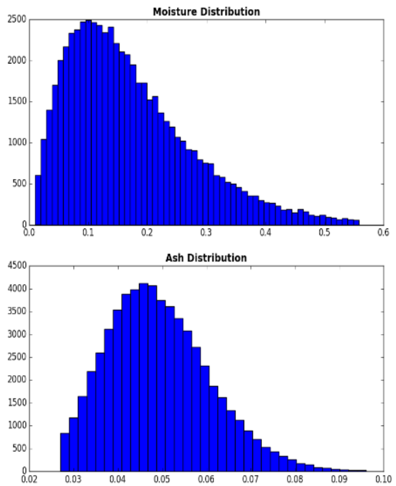


Node	Identifier	County	Capacity (dry tons/yr)	Biomass Type	Biomass Source Nodes
-	Biorefinery	Sheridan, KS	800,000	Blend	4, 6, 12, 14
4	Depot	Harlan, NE	400,000	two-pass corn stover	2, 3, 4, 7
6	Depot	Furnas, NE	360,000	three-pass corn stover	6
				two-pass corn stover	2, 5, 8
12	Depot	Graham, KS	80,000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

3 – Technical Accomplishments (continued)

OPERATIONAL RELIABILITY MODEL

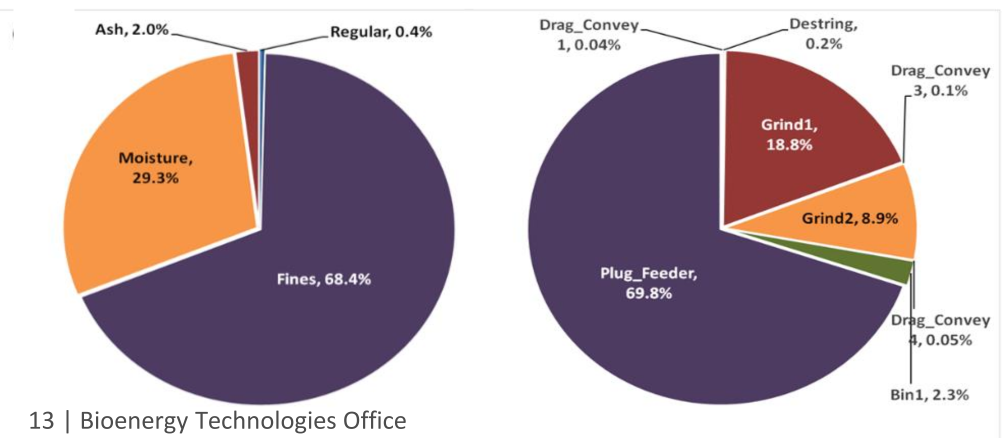
Moisture & Ash Distributions



Equipment Performance

First Stage Grinder	
Regular Failure	
Mean time to failure	6 months
Mean repair time	2 hours
Repair time standard deviation	30 minutes
Ash Caused Failure	
Cumulative ash processed	500 tons
Mean repair time	6 hours
Repair time standard deviation	2 hours
Moisture Caused Failure	
Maximum moisture content	35%
Mean repair time	30 minutes
Repair time standard deviation	15 minutes

1-year Discrete Event Simulation (DES)



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*

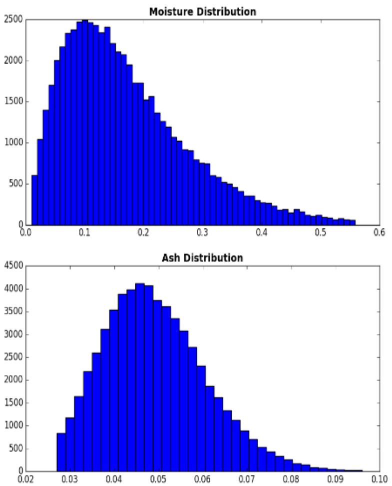
ANALYSIS ACCOMPLISHMENT

- 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

Moisture & Ash Distributions



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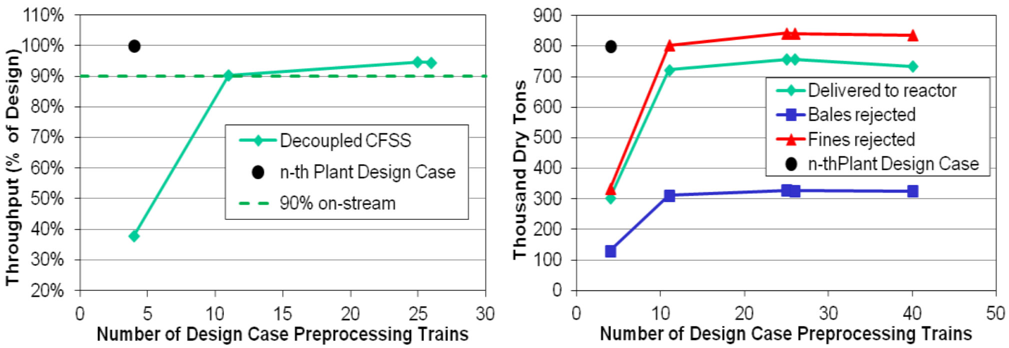


3 – Technical Accomplishments (continued)

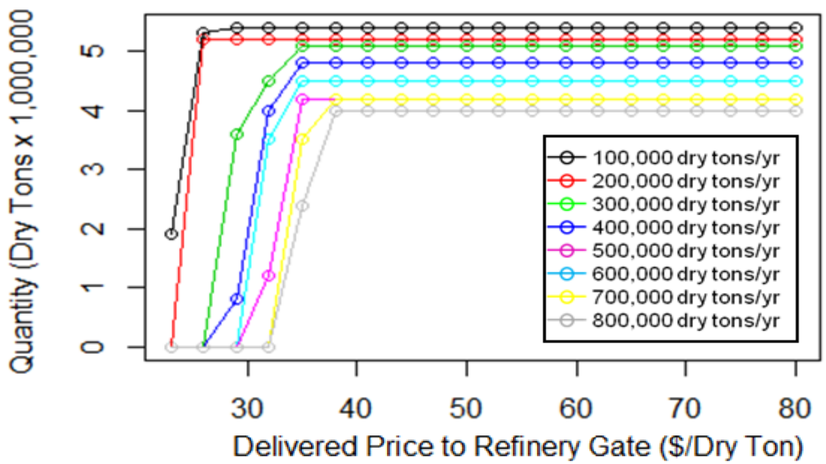
BIOREFINERY SUPPLY ASSESSMENT MODEL

(e.g. Pine Logging Residues)

ANALYSIS ACCCOMPLISHMENT

- 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

NATIONAL ANALYSIS



REGIONAL ANALYSIS

	200,000 dt capacity			400,000 dt capacity			600,000 dt capacity			800,000 dt capacity		
Region	$26/dt	$32/dt	$38/dt	$26/dt	$32/dt	$38/dt	$26/dt	$32/dt	$38/dt	$26/dt	$32/dt	$38/dt
Mountain	0	269036.2	265899.9	0	0	191068.3	0	0	0	0	0	0
Northern Plains	0	101509.9	105470.9	0	0	0	0	0	0	0	0	0
Southern Plains	143746.3	212992.6	220770.1	0	202989.1	220973.2	0	0	198353.1	0	0	219546.1
Heartland	0	0	0	0	0	0	0	0	0	0	0	0
Northeastern	250.8	192.28	6522.605	0	2639.005	935.085	0	0	5404.17	0	0	3411.165
Southern	759460.7	952061	952502.2	0	932102.3	962344.6	0	440737.1	860749.9	0	0	909698.9
Pacific	286104.8	371076.9	223277.4	0	292670.7	315249.4	0	0	371076.9	0	0	363671.3
Northwest	545254.6	1113703	1140855	0	441036.9	892679.4	0	0	577513.8	0	0	436328.7
Delta	452987.9	583061.5	601029.6	0	618726.2	656499.6	0	11247.05	634789.6	0	0	601248.2
Eastern Mountain	145364.5	380742.5	359661.8	0	362473.4	317838.5	0	953.135	329424.4	0	0	354575.4
Upper Midwest	0	0	0	0	0	0	0	0	0	0	0	0
Great Lakes	0	2866.625	6019.58	0	0	5323.895	0	0	539.79	0	0	3999.5

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

3 – Technical Accomplishments (continued)

SIGNIFICANT DELIVERABLES

FY17

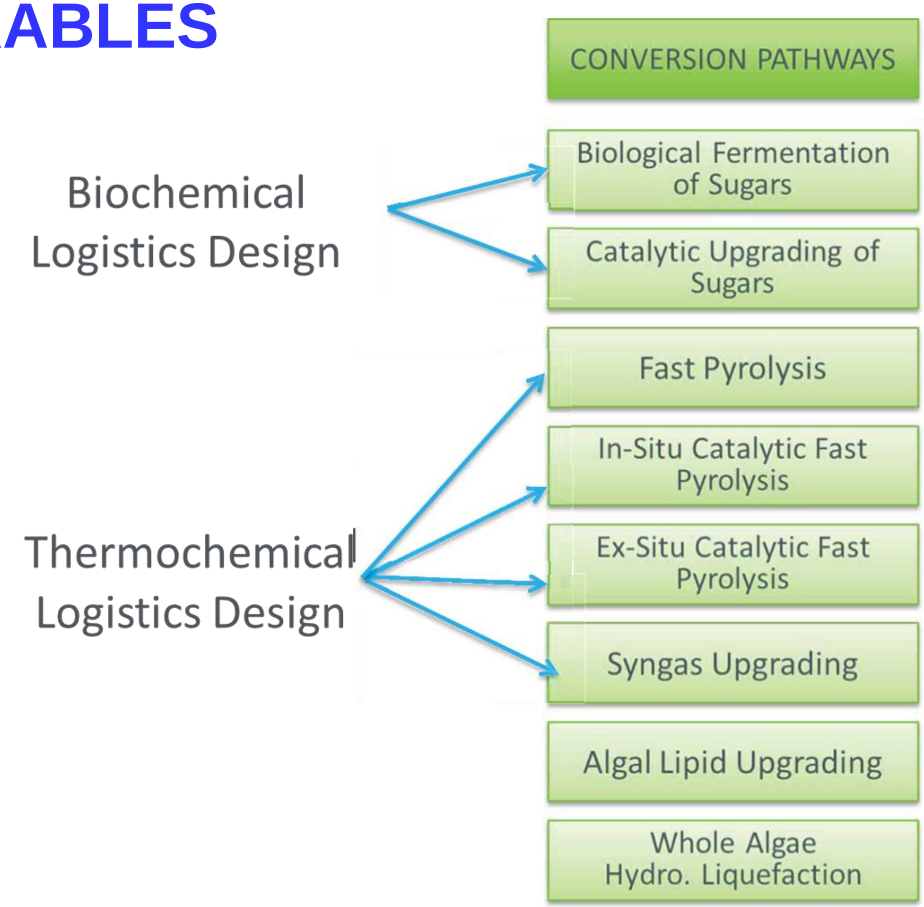
- 2017 Woody SOT (1 pathway)
- 2017 Herbaceous SOT (1 pathway)
- Go/No-go Report: Determination of advanced feedstock supply systems as a viable option for meeting BETO cost, volume, and quality targets

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

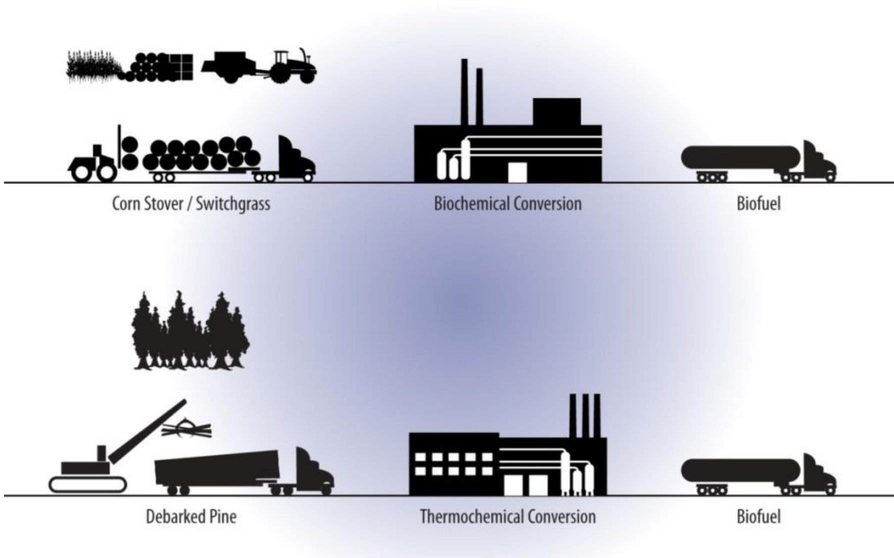
4 – Relevance

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*

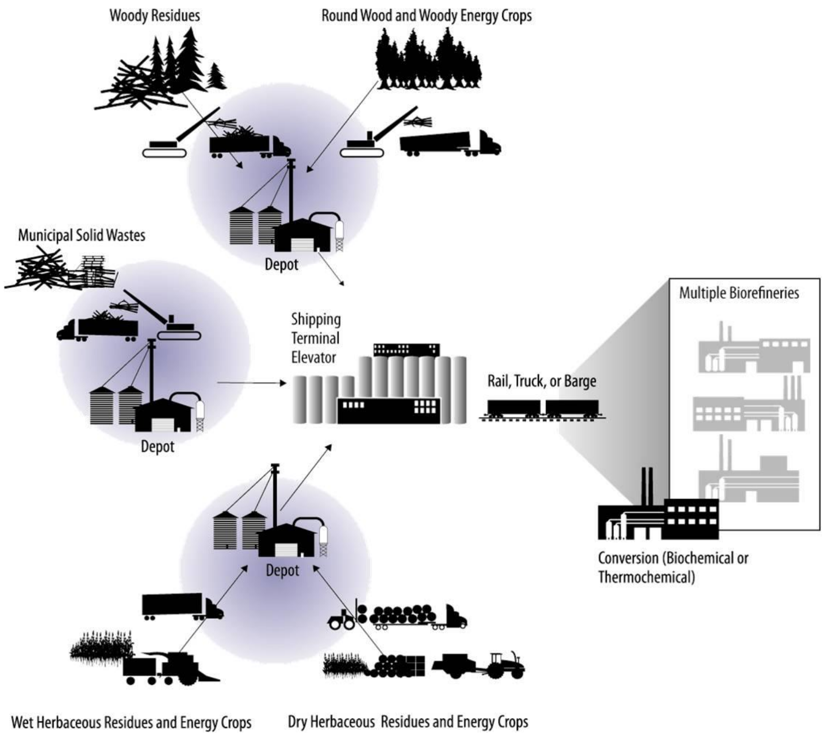
4 – Relevance (continued)

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



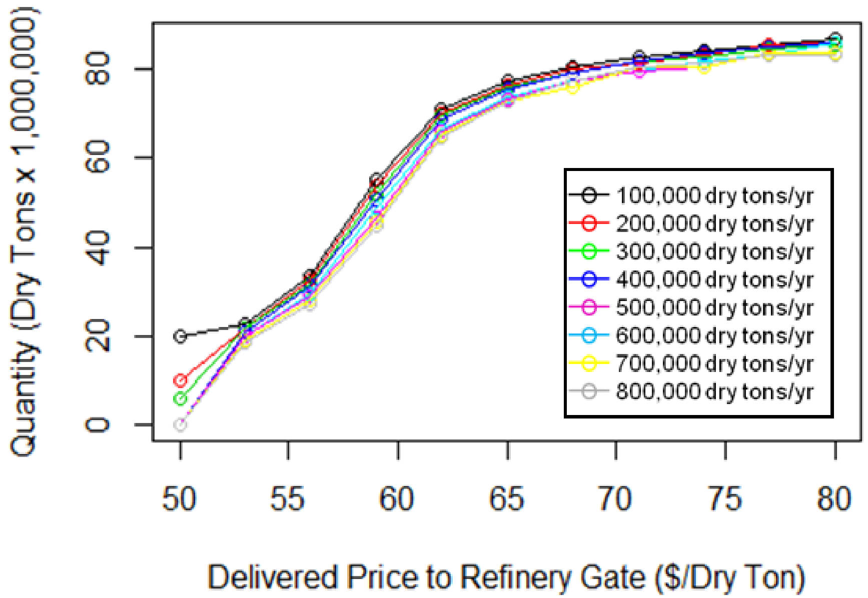
An AFSS dynamically provides a "conversion-ready" engineered feedstock from a myriad of diverse raw biomass sources, and decouples the supply of this engineered feedstock from the biorefinery infeed. "Conversion-ready" implies that the engineered feedstock meets all quality specifications for the specific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

National Analysis – 3-pass Corn Stover



Regional Analysis – 3-pass Corn Stover

Table 1 Regional Quantities Delivered by Price and Refinery Size

	200,000 dt capacity			400,000 dt capacity			600000 dt capacity			800000 dt capacity		
Region	**\$56/dt**	**\$74/dt**	**\$80/dt**	**\$56/dt**	**\$74/dt**	**\$80/dt**	**\$56/dt**	**\$74/dt**	**\$80/dt**	**\$56/dt**	**\$74/dt**	**\$80/dt**
Mountain	24413.91	483163	721816.1	36945.3	724071	791513.9	0	918221.2	946674.5	207.555	882536.9	964745.2
Northern Plains	16153019	19314714	20986294	15981318	21146111	20664696	15978417	20719716	20723406	15737332	21577226	21063286
Southern Plains	210645.5	765661.2	867649.5	176427.4	952182	830725.3	0	803752.2	730696	0	996224.3	910941.3
Heartland	2165504	9169356	9446969	2583618	9181652	9068388	2094669	9089485	9078882	896361.5	8980427	9227866
Northeastern	0	1839946	2028578	0	1971859	1982923	0	2042978	1751575	0	1923633	1746611
Southern	0	380666.9	444311.2	0	438557.5	441282.7	0	275124.7	283497.3	0	108507.7	109559.6
Pacific	507115.2	756739.7	776169.4	400000	782546	782546	600000	600000	600000	0	800000	800000
Northwest	0	0	0	0	0	0	0	0	0	0	0	0
Delta	0	903117.9	996215.1	0	982764.6	926739.2	0	1055902	1029443	0	996666.1	906392.5
Eastern Mountain	200000	1594458	1789231	0	1844604	1847471	0	1797282	1777950	0	1689606	1492322
Upper Midwest	7026616	25921414	26424555	6752070	25901699	26738771	6496677	24799772	26984451	6922434	25600714	24958065
Great Lakes	2000000	9779257	10139925	1200000	10163872	10369482	0	9705770	10265860	0	10372614	10415576

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

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Questions?

Source: http://karenshulman.com/portfolio-view/running-effective-meetings/

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Additional Slides

Responses to 2017 Peer Review Comments

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.

Responses to 2017 Peer Review Comments

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

1. Roni, M.S., Thompson, D., Hartley, D., Searcy, E., & Nguyen, Q. (2018). Optimal blending management of biomass resources used for biochemical conversion. Biofuels, Bioproducts and Biorefining, 12(4), 624-648.
2. Roni, M., Thompson, D. N., Hu, H., Hartley, D, Nguyen, Q. & Cai, H. (2017). Herbaceous Feedstock 2017 State of Technology Report, Idaho National Laboratory, Idaho Falls, ID, INL/LTD-17-43738 Rev. 3.
3. Hartley, D., Thompson, D., Hu, H, Cai, H. (2017). Woody Feedstock 2017 State of Technology Report. Idaho National Laboratory, Idaho Falls, ID, INL/LTD-17-43459 Rev. 2.
4. Roni, M., Thompson, D., Hartley, D., Griffel, M.,Nguyen, Q., Cai,H. (2018). "Herbaceous Feedstock 2018 State of Technology Report" Idaho National Laboratory, Idaho Falls, Idaho, INL/EXT-18-51654.
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PUBLICATIONS SUPPORTED BY ANALYSIS FROM THIS PROJECT

1. Roni, M.S., Chowdhury, S., Mamun, S., Marufuzzaman, M., Lein, W., & Johnson, S. (2017). Biomass co-firing technology with policies, challenges, and opportunities: A global review. Renewable and Sustainable Energy Reviews, 78, 1089-1101.
2. Quddus, M.A., Hossain, N.U.I., Mohammad, M., Jaradat, R.M., & Roni, M.S. (2017). Sustainable network design for multi-purpose pellet processing depots under biomass supply uncertainty. Computers & Industrial Engineering, 110, 462-483.
3. Davis, R., N. Grundl, L. Tao, M.J. Biddy, E.C.D. Tan, G.T. Beckham, D.Humbird, D.N. Thompson and M.S. Roni (2018). Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbon Fuels and Coproducts: 2018 Biochemical Design Case Update (NREL/TP-5100-71949).
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Publications (continued)

5. Tan, E.C.D., Ruddy, D., Nash, C., Dupuis, D., Dutta, A., Hartley, D., and Cai, H (2018). High-Octane Gasoline from Lignocellulosic Biomass via Syngas and Methanol/Dimethyl Ether Intermediates: 2018 State of Technology and Future Research. (NREL/TP-5100-71957).
6. Cai, H., Dunn, J., Pegallapati, A., Li, Q., Canter, C., Tan, E., Biddy, M., Davis, R., Markham, J., Talmadge, M., Hartley, D., Thompson, D.N., Meyer, P.A., Zhu, Y., Snowden-Swan, L., Jones, S. (2017). Supply Chain Sustainability Analysis of Renewable Hydrocarbon Fuels via Indirect Liquefaction, Fast Pyrolysis, and Hydrothermal Liquefaction: Update of the 2016 State-of-Technology Cases and Design Cases. Argonne National Laboratory, Chicago, IL., ANL-17/04.
7. Thompson, V.S., J.E. Aston, J.A. Lacey and D.N. Thompson. (2017). Optimizing biomass feedstock blends with respect to cost, supply, and quality for catalyzed and uncatalyzed fast pyrolysis applications. BioEnergy Research 10(3), 811-823.
8. Narani, A., Konda, N.V.S.N.M, Chen, C.-S., Tachea, F., Coffman, P., Gardner, J., Li, C., Ray, A.E., Hartley, D.S., Simmons, B., Pray, T.R., Tanjore, D. 2019. Simultaneous application of predictive model and least cost formulation can substantially benefit biorefineries outside Corn Belt in United States: A case study in Florida. Bioresource Technology. 271:218-227.
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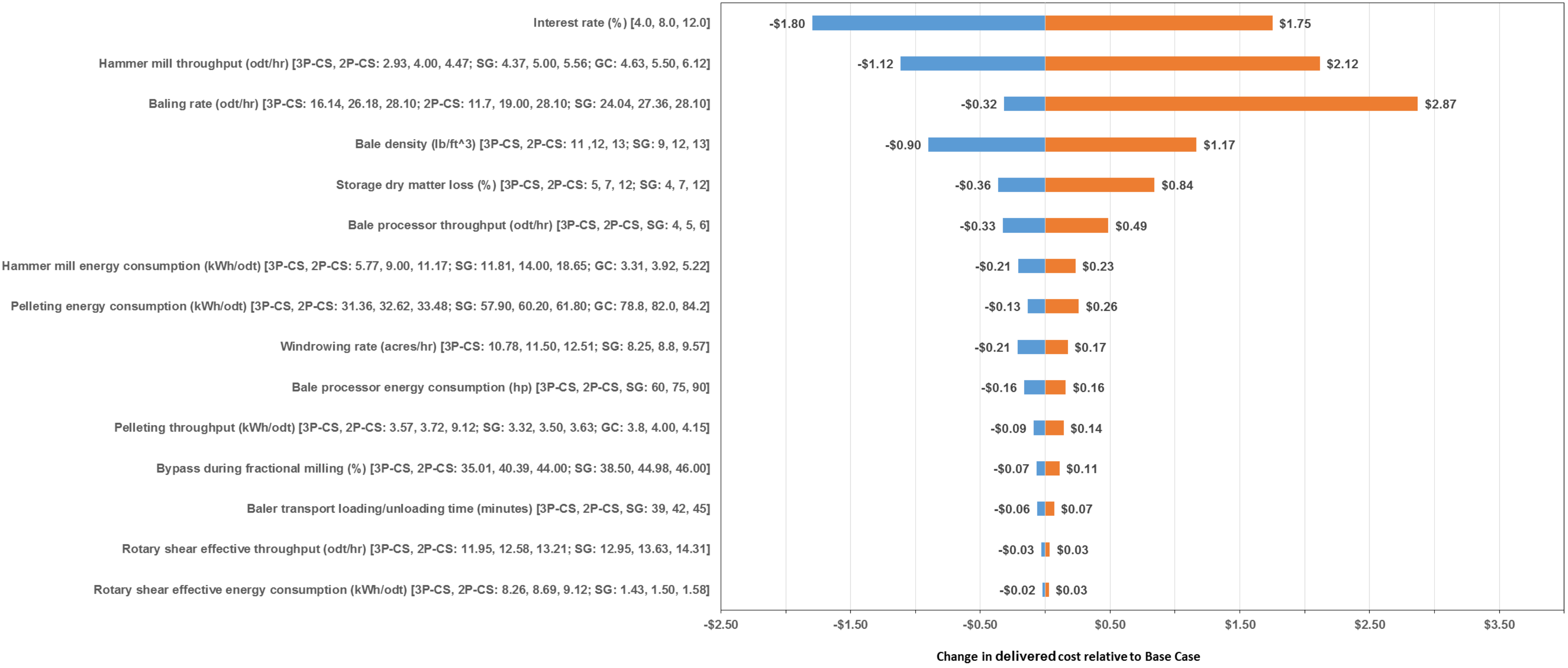
10. Westover, T.L, Hartley, D.S. 2018. Biomass Feeding and Handling. In: Biofuels-Past, Present and Future. ISBN: 978-953-51-5881-3.
11. Ray, A.E., Li, C., Thompson, V.S., Daubaras, D.L., Nagle, N.J., Hartley, D.S. 2017. Biomass Blending and Densification: Impacts on Feedstock Supply and Biochemical Conversion Performance. In Biomass Volume Estimation and Valorization for Energy. InTech.

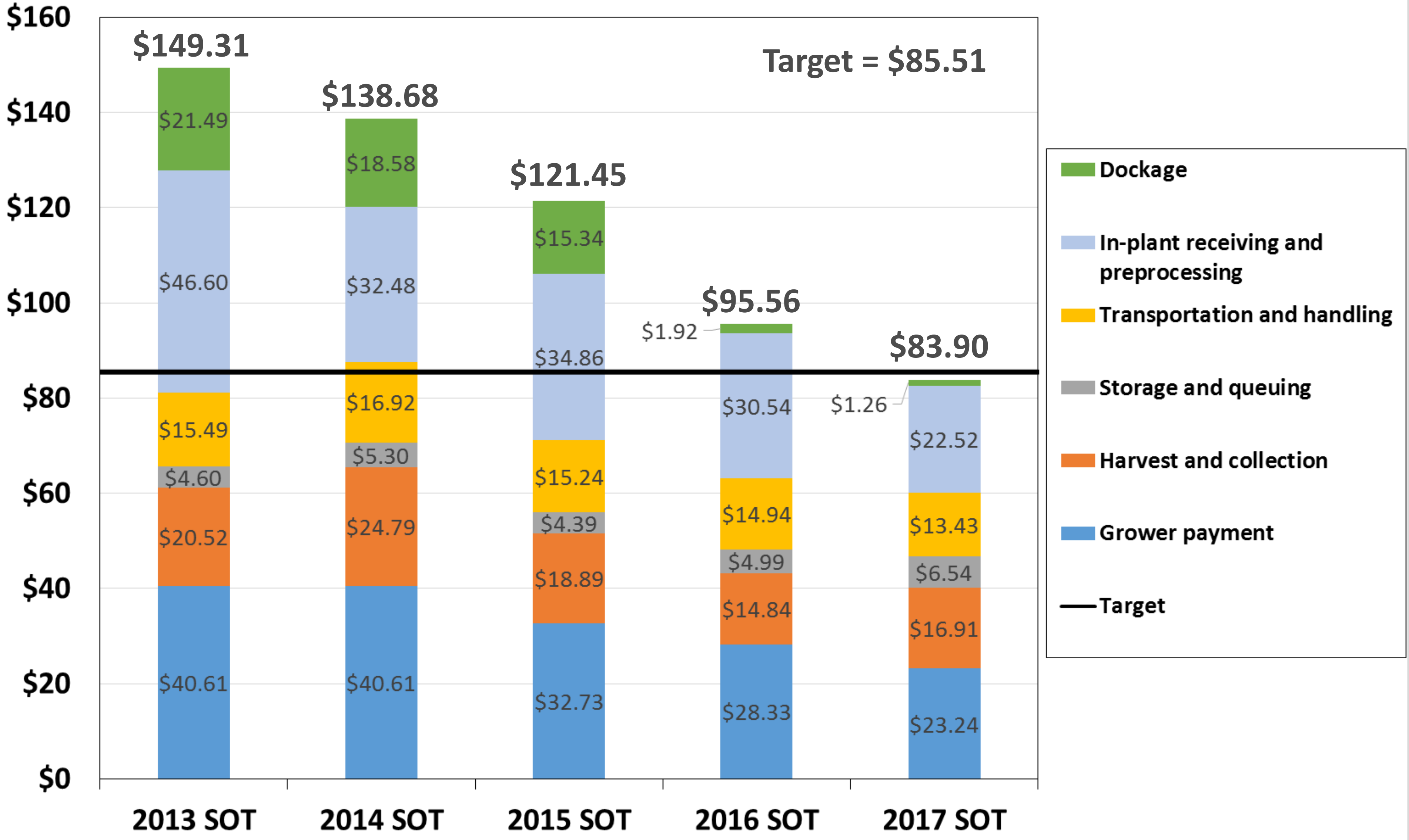
Supporting Slides

3 – Technical Accomplishments (continued)

SENSITIVITY ANALYSIS 2022 HERBACEOUS PROJECTION

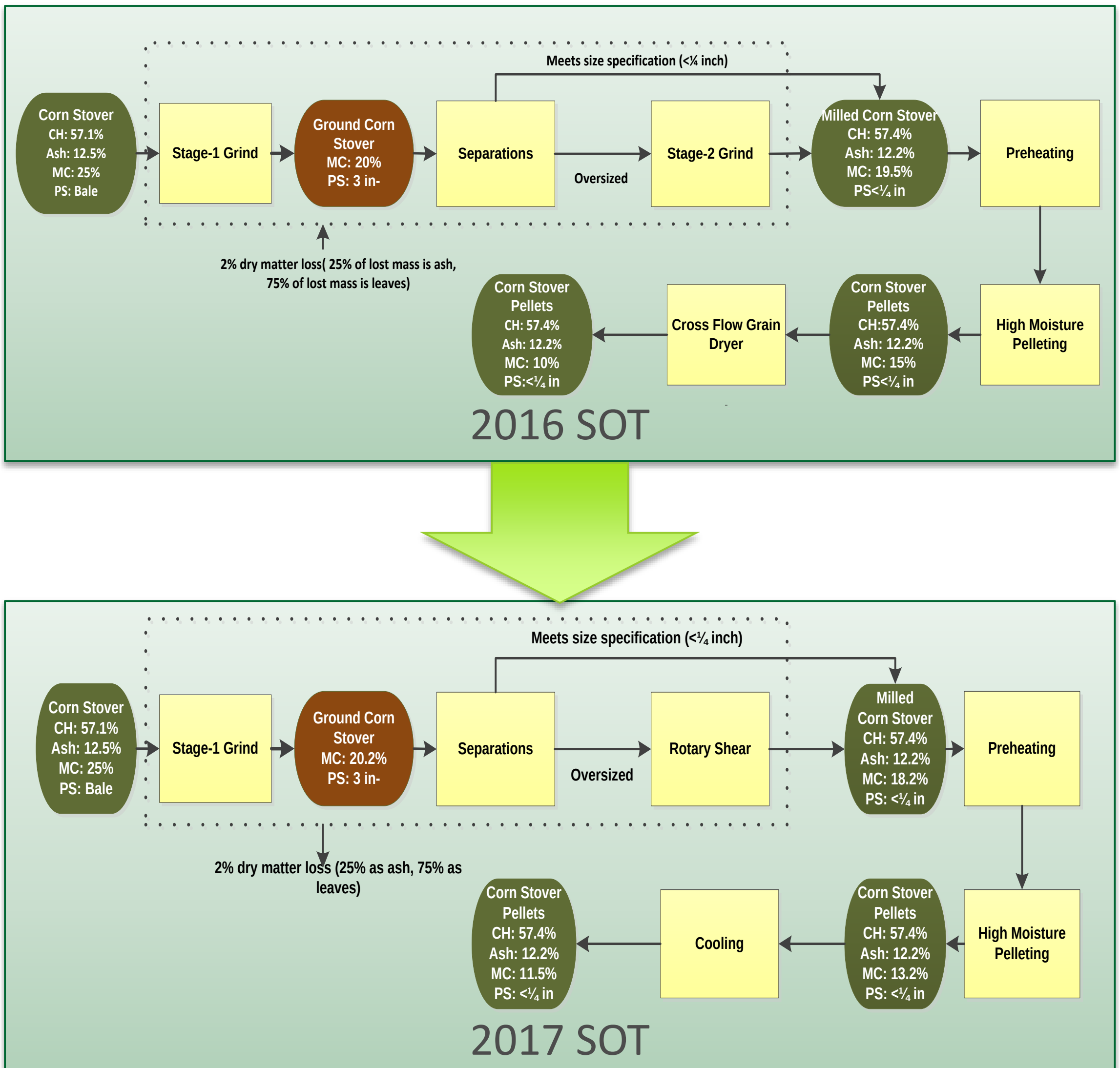


3 – Technical Accomplishments (continued)



3 – Technical Accomplishments (continued)

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_2e/ton GHG emission reduction for in-plant receiving and biomass preprocessing