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U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) 2017 Project Peer Review

1.1.1.2 Feedstock Supply Chain Analysis

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Feedstock Logistics

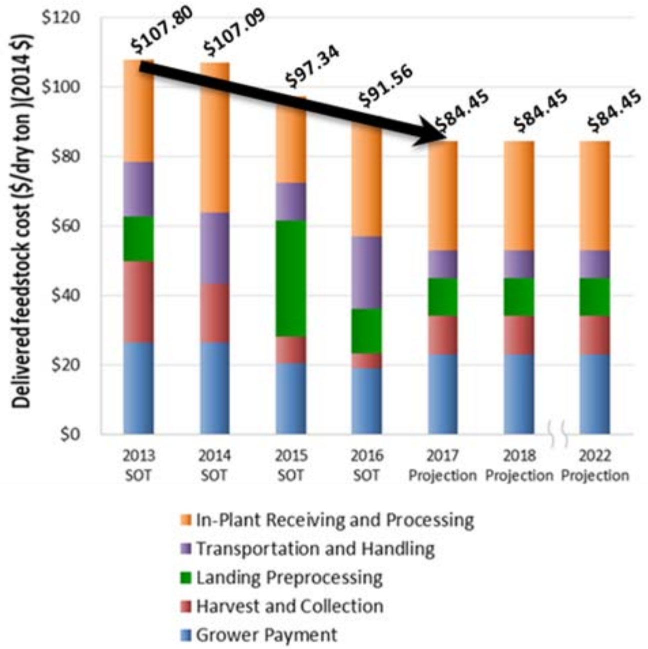
David N. Thompson, Ph.D.

Idaho National Laboratory

Goal Statement

Goals

- Leading-edge feedstock analyses that
  - Identify R&D technology performance and cost targets to achieve BETO programmatic goals
  - Track programmatic progress towards these goals
  - Provide verification that programmatic goals were achieved



Outcomes

- Demonstrate how BETO-funded RD&D over the past 5 years collectively contributed to meeting cost targets
- Significantly expand beyond feedstock cost metrics to provide the first definitive and comprehensive analysis of conventional and advanced feedstock supply systems

Relevance to the bioenergy industry

- Assesses cost competitive ways for incorporating widely distributed and variable quality biomass resources into bioenergy feedstocks
- Assesses system-wide cost impacts of BETO-funded technology improvements
- Evaluates tradeoffs and interdependencies among modeled cost, quality, resource availability, environmental performance, risk, technological advancements, and logistical improvements

Quad Chart Overview

Timeline

- Project start date: Oct. 1, 2005
- Project end date: NA
- This project is foundational to the BETO FSL portfolio and is an ongoing project

Budget

	Total Costs FY 12 – FY 14	FY 15 Costs	FY 16 Costs	Total Planned Funding (FY 17-Project End Date)
DOE Funded	$1.506M	$604K	$850K	$900K
Project Cost Share (Comp.)*	NA	NA	NA	NA

Barriers

- Ft-A. Terrestrial Feedstock Availability and Cost
- Ft-I. Overall Integration and Scale-Up
- MYPP Technical Targets addressed
  - $84/dry ton modeled cost target
  - 285 million tons mobilized by 2022
- Lack of data for many biomass resources

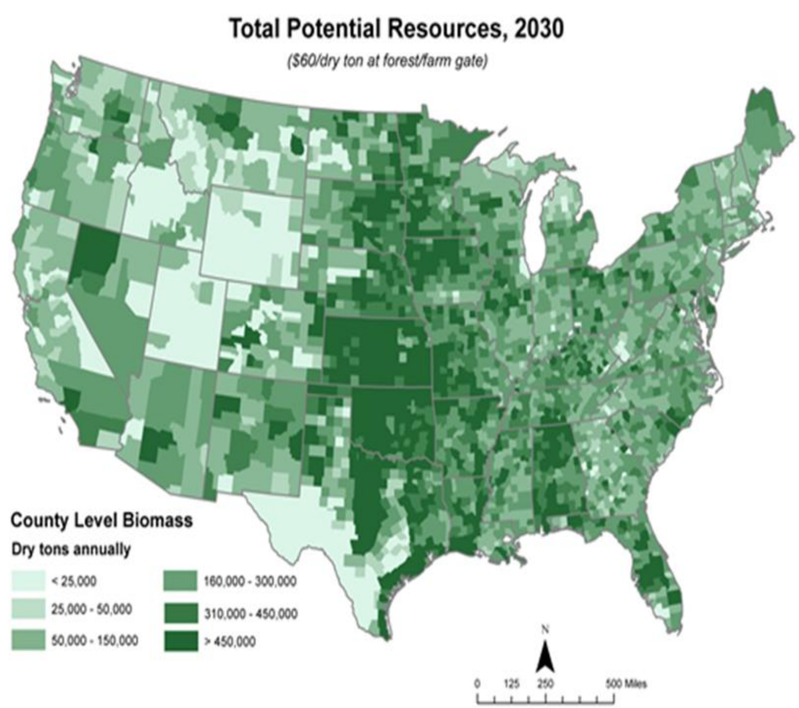
Partners/Collaborators

- All FSL R&D AOP Projects
- Industry projects (data source)
- Other BETO National Laboratories performing TEA and LCA

1 – Project Overview

HISTORY

- FY12 Design: Conventional supply system in high yielding region
- FY13 Design: Conventional supply system in lower-yielding but more diverse region
- FY17 Design: Advanced supply system incorporating decoupling from the biorefinery, blended conversion-ready feedstocks, active quality management and densified, flowable format



CONTEXT

- Cost, quantity, quality & sustainability all matter
- High potential availability but widely distributed
- Wide variation of physical properties and chemical composition makes meeting specs difficult

OBJECTIVES

- Demonstrate how BETO-funded R&D collectively contributed to meeting achievement of the FY17 $84/ton modeled cost target
- Demonstrate how BETO-funded R&D collectively contributed to modeled cost reductions of at least $63/ton and $23/ton relative to the 2013 TEAs of biochemical and thermochemical pathways, respectively
- Significantly expand beyond feedstock cost metrics to include risk, reliability and other currently unaccounted for costs

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 platform (e.g., BT16, BSM)
- Bi-weekly conference calls with BETO
- 5-7 milestones per year
  - Quarterly Progress milestones
  - SMART Annual Milestones for high-impact deliverables and outcomes

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

2 – Approach (Technical)

TECHNICAL APPROACH

- Develop design reports to identify specific technical cost targets for achieve technical cost targets
- Track annual progress toward BETO cost and technical targets established in the design report (SOT reports)
- Look beyond the current design report to identify advanced systems that can mobilize resources and overcome IBR-identified problems
- Develop new computational tools where necessary to expand analysis capabilities to answer new questions

TOP 3 TECHNICAL CHALLENGES

- Existing paradigms related to feedstock supply
- Credibly modeling costs that are not yet recognized as costs
- Lack of complete harvest, composition, preprocessing and convertibility datasets across multiple biomass resources

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

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2 – Approach (Technical) (continued)

CRITICAL SUCCESS FACTORS

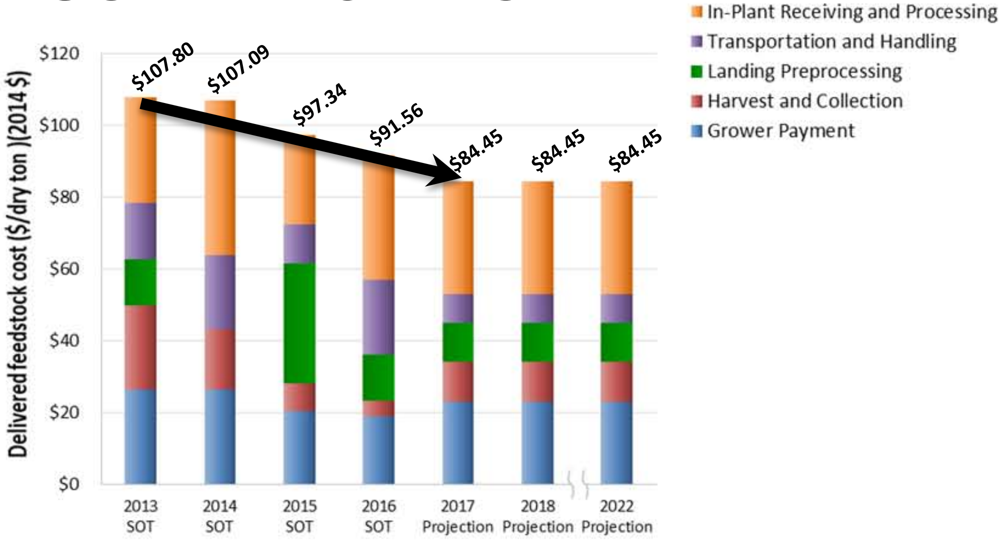
- Technical
  - Design reports with plausible pathways to meeting targets
  - Integrated analyses that account for cost, quality, resource availability, environmental performance, risk, technological advancements, and logistical improvements
  - Supply system designs that provide value across the supply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

SOT TRACKING



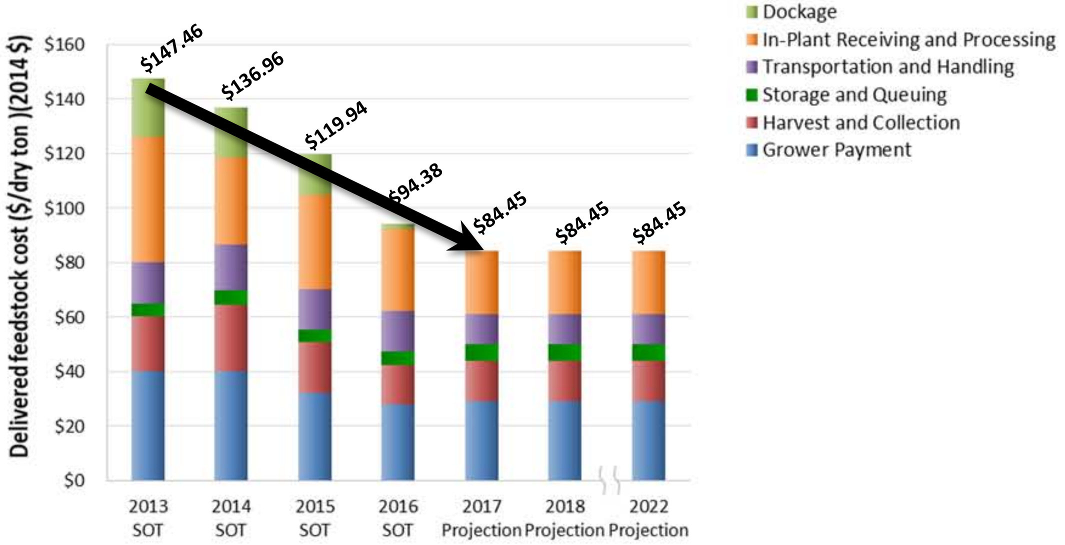
2017 feedstock cost target: total delivered feedstock cost of $84.45/dry ton, including both grower payment and logistics cost

***Woody biomass**: Historical and projected delivered feedstock cost, modeled for pyrolysis conversion.*

Target spec: 10% MC, 0.08 in., ≤ 0.9% ash

***Herbaceous biomass**: Historical and projected delivered feedstock cost, modeled for biochemical conversion.*

Target spec: 20% moisture, 5% ash, 59% total carbohydrates



3 – Technical Accomplishments (continued)

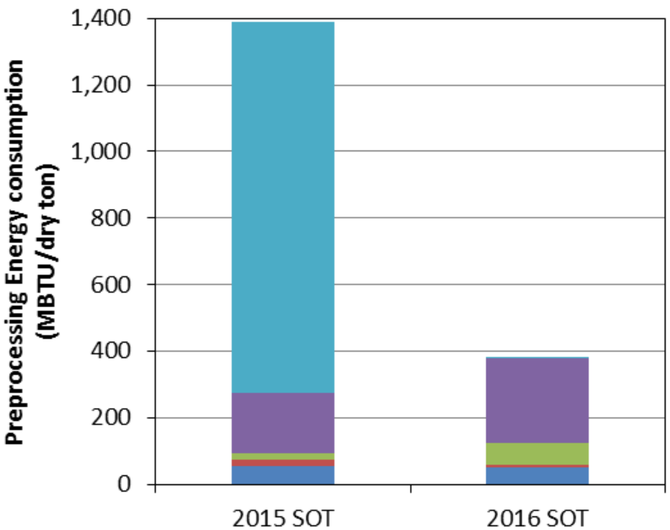
SOT TRACKING EXAMPLE

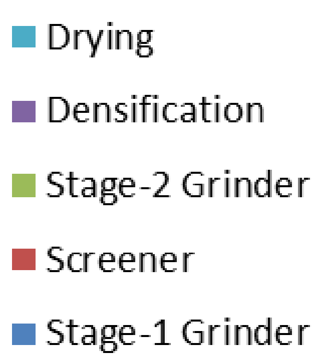
R&D ACHIEVEMENT

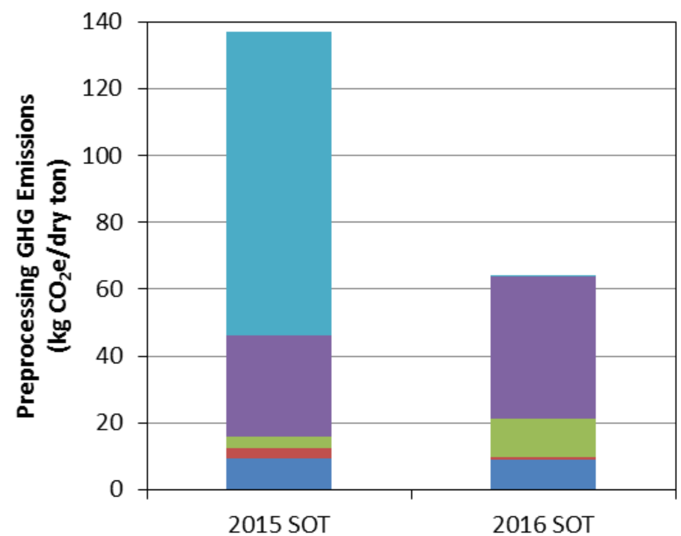
- Incorporating both fractional milling and high moisture densification

ANALYSIS ACHIEVEMENT

- Iterating between R&D and analysis
- Continuing the gradual transition to advanced systems







3 – Technical Accomplishments (continued)

NEW TOOLS - Expanded Computational Capabilities

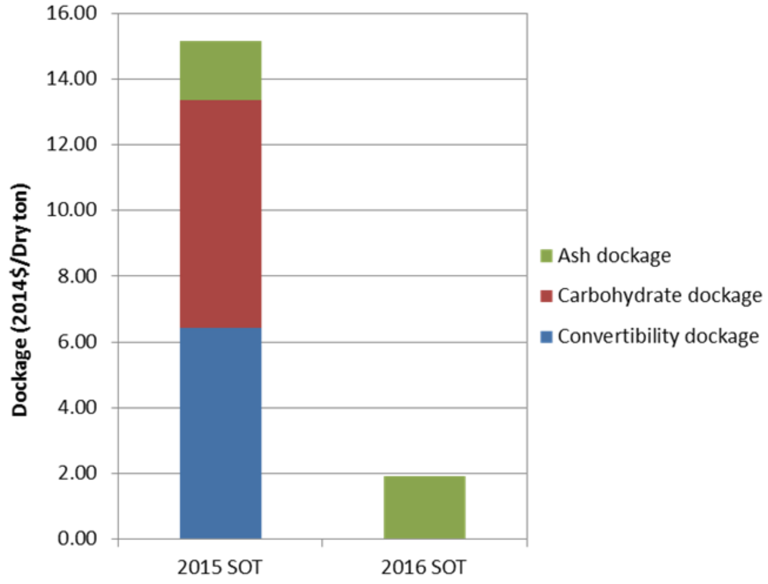
- *Biomass Logistics Model historically provided only cost analyses*
- *New state-of-the-art tools/add-ins developed to provide advanced analysis*

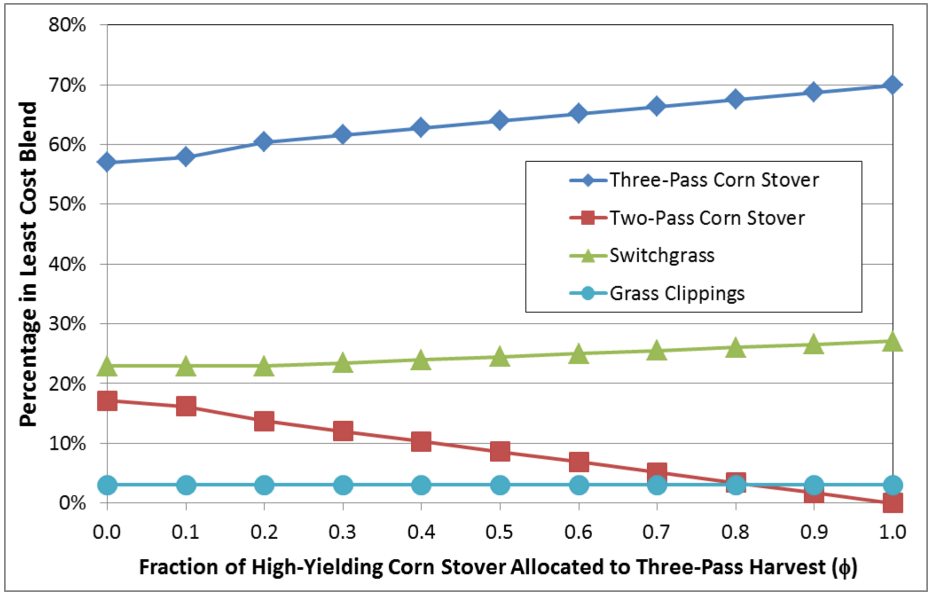
New Model	New Capability
Advanced Feedstock Supply Systems Analysis Model	• Quantify stranded biomass resources • Impacts of remote depots and depot sizing on resource accessibility and cost
Expanded Least Cost Formulation Model**	• Integration of preprocessing cost • Selects resources based on total supply system costs, not only on farm gate price • Optimal feedstock blend based on cost, quality and resource availability
Biomass Logistics Model: Discrete Event Simulation Module	• Dynamic simulation of the supply system • Monte Carlo analysis and operational reliability impacts as a function of biomass variability
Biomass Logistics Model: Quality Module	• Linkage to dynamic reliability assessment • AspenPlus compatibility with conversion models

*** This model will be integrated into the Library's Least Cost Formulation Tool*

3 – Technical Accomplishments (continued)

NEW TOOL IMPACT ON SOT





ACHIEVEMENT

- Expanded approach to least-cost formulation
  - Improved by allowing for the collection of low cost resources from a further distance
  - Will be integrated into the Library least cost formulation tool

SIGNIFICANCE AND IMPACT

- Important step in controlling quality and eliminating dockage
- Switchgrass and grass clippings integration is a realistic scenario for how they can enter the supply chain
- Reduced dockage by 87.5% ($1.90 vs. $15.15/dry ton)
  - Eliminated carbohydrate dockage
  - Eliminated convertibility dockage
- Harvest and Collection reduced by $4.00/dry ton
- Demonstrated potential for dynamic blending given biomass sources of varied quality

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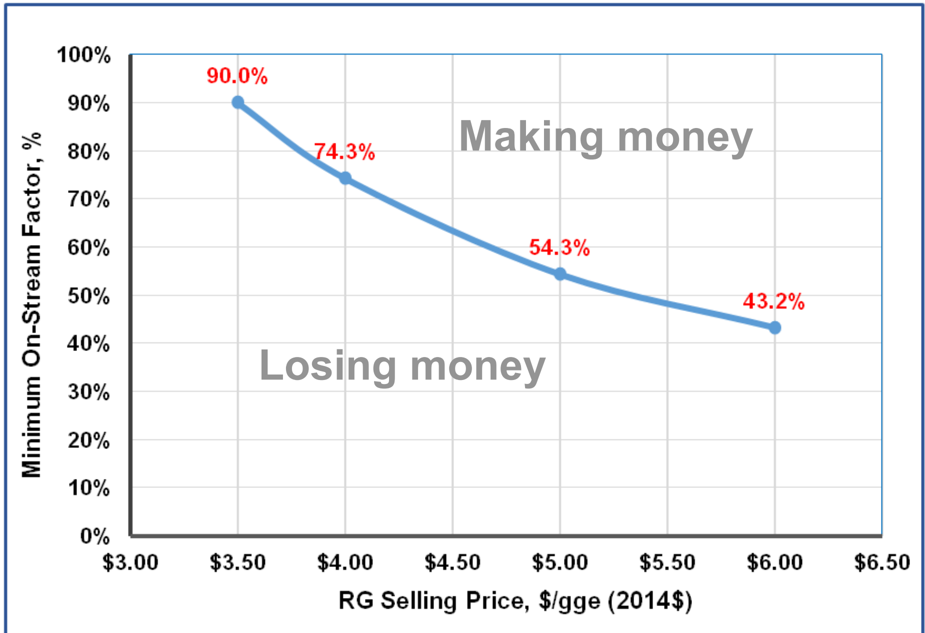
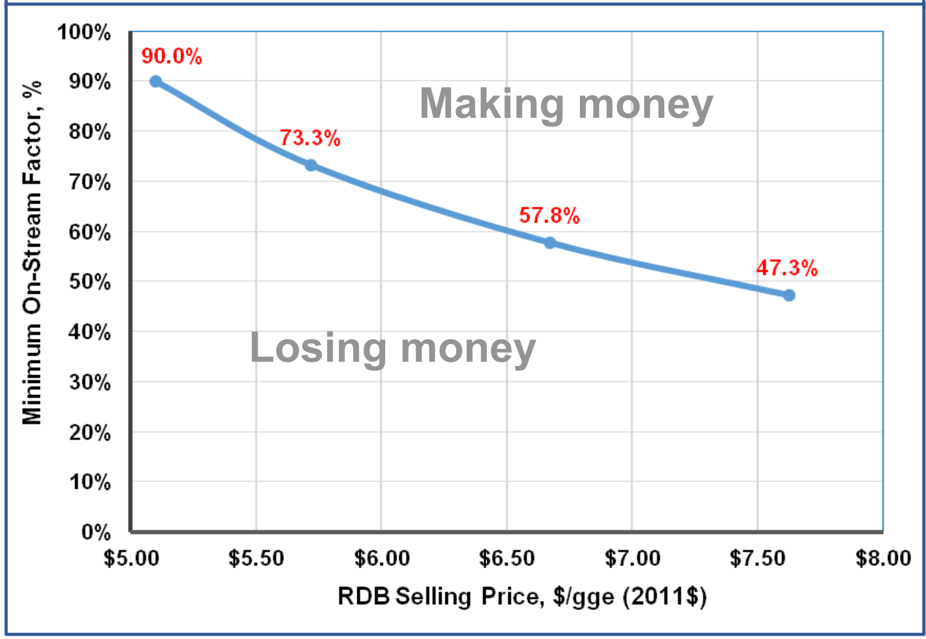
3 – Technical Accomplishments (continued)

ADDRESSING IBR ISSUES

- IBR experience is that handling and feeding ground biomass is a significant barrier (poor reliability)
- Collaborating with PNNL and NREL to quantify biorefinery cost impacts of reduced throughput on conversion design cases
  - Current fast pyrolysis design case for production of renewable gasoline (RG)
  - 2013 design case for production of renewable diesel blend (RDB)
- Two new computational modeling tools developed to assess the cost impacts, analysis is underway





3 – Technical Accomplishments (continued)

FORWARD-LOOKING TARGET DEVELOPMENT

- BETO success indicators for biofuels have historically been based only on potential biofuel volumes, which does not show the importance of the prerequisite feedstock supply mobilization
- There is a need for long term targets for feedstock supply mobilization that go beyond delivered cost
  - Develop success indicators spanning economy-wide impacts such as domestic jobs, manufacturing expansion, etc.
  - Identify analyses needed
- Ten feedstock mobilization success indicators
  - Mobilizing biomass resources
  - Displacing foreign oil
  - Reducing GHG emissions
  - Building the US and rural economies
  - Partnering with industry
  - Feedstock commoditization
  - Financing feedstock supply expansion
  - Cross-cutting industry impacts
  - Policy and regulatory challenges
  - Biomass supply/demand dynamics

Source: http://www.flickr.com/photos/kohtz/234620719/

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3 – Technical Accomplishments (continued)

SIGNIFICANT DELIVERABLES

FY15

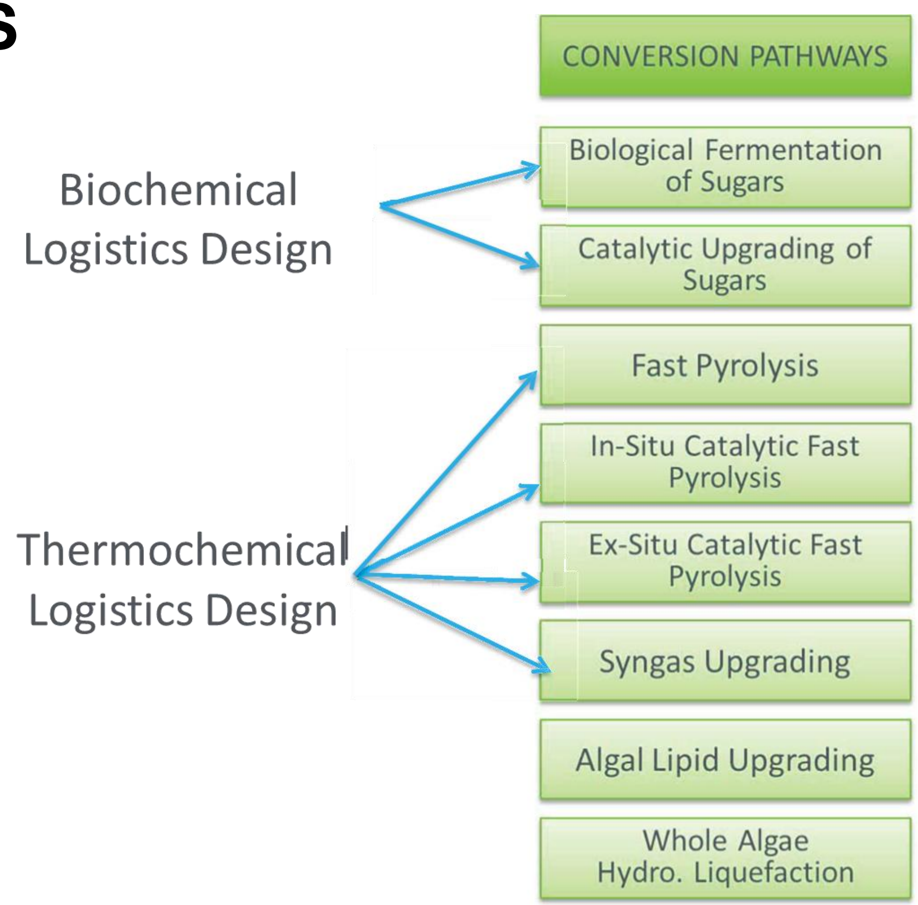
- 2015 Woody and Herbaceous SOTs
- Advanced Feedstock Supply Validation Workshop Summary Report
- Analysis of depot sizing and access to stranded resources through the advanced depot design

FY16

- 2016 Woody and Herbaceous SOTs
- Validation of dockage costs in the Biochemical Platform with NREL
- Regional Feedstock Partnership Summary Report

FY17 Q1

- Biomass mobilization indicators spanning economy-wide impacts such as domestic jobs, manufacturing expansion, etc.



State of Technology reports (SOTs) directly support the 6 terrestrial feedstock conversion TEAs

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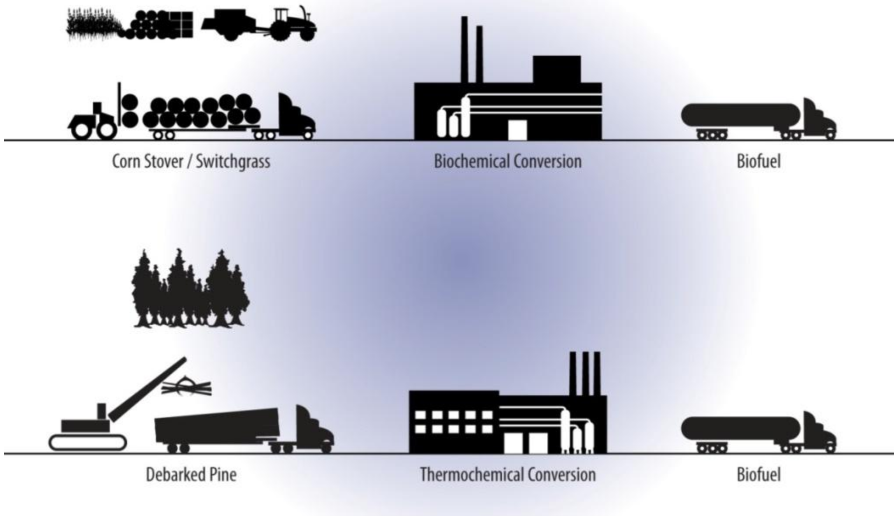
4 – Relevance

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 IBRs
- 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*

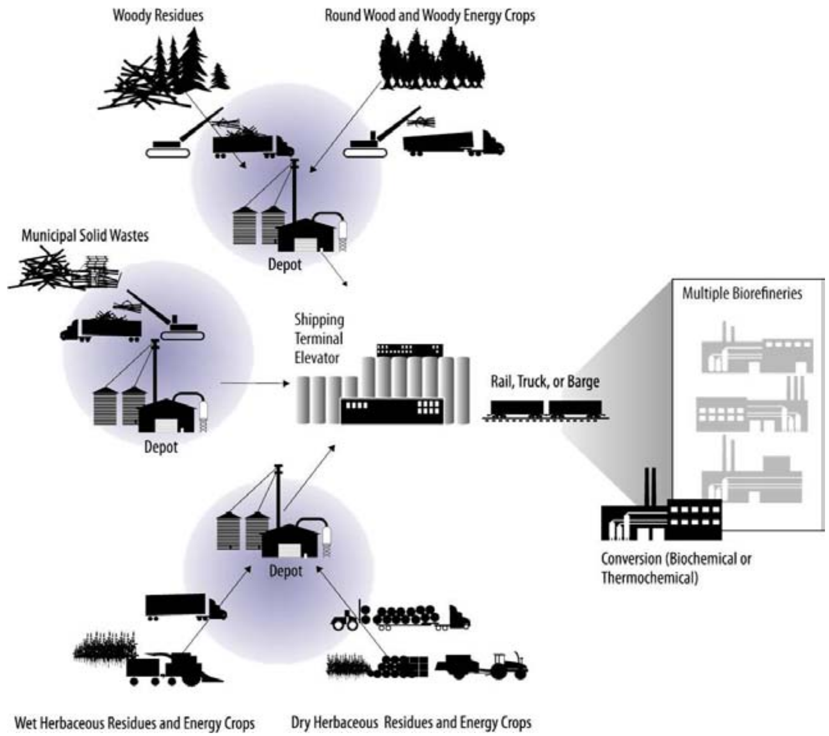
4 – Relevance (continued)

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 IBR 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.

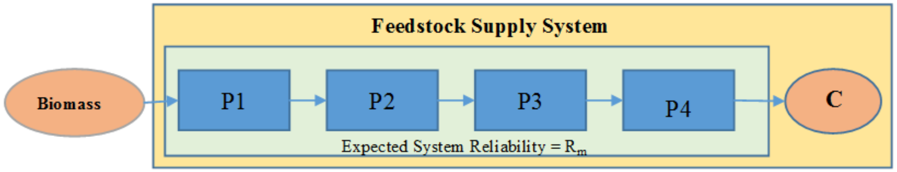
5 – Future Work

PLANS THROUGH FY17 (AND BEYOND)

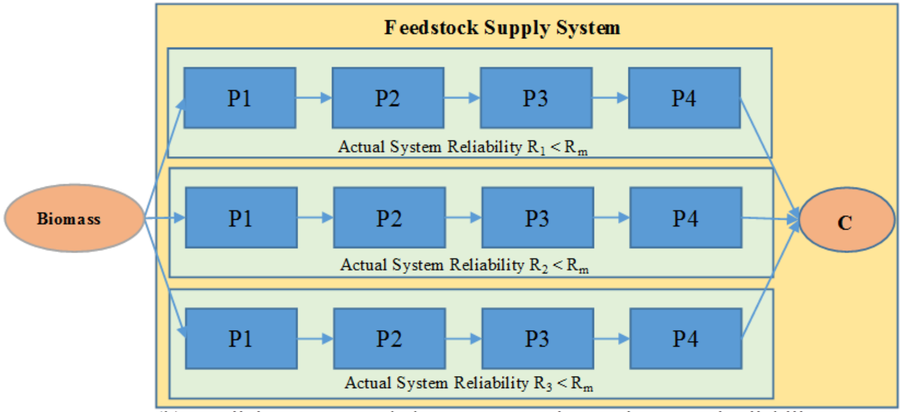
- Advanced Feedstock Supply System definition and analysis
  - Identify metrics for comparing AFSS to CFSS in terms of
    - <u>Supply system operational reliability</u>

      bulk density, particle size distribution, flowability, compactibility, minimal durability for handling and storage
    - <u>Business and process economics</u>

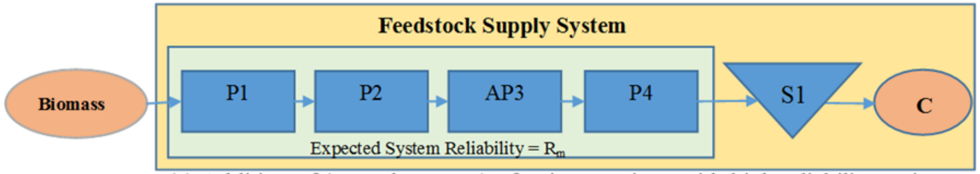
      equipment manufacturing, transportation infrastructure, storage requirements, etc.
    - <u>Provide integrated analysis</u> to support a March 31, 2017 Go/No-go decision for AFSS
- State of Technology analysis and reporting



(a) System designed to meet capacity C at manufacturer reliability R_m



(b) Parallel systems needed to meet capacity C when actual reliability $R_i < R_m$



(c) Addition of (or replacement) of unit operations with high reliability unit operations such as pelleting, and decoupling supply from biorefinery operation.

5 – Future Work (continued)

UPCOMING KEY MILESTONE

- September 30, 2017: Deliver annual State of Technology design for the biochemical and thermochemical design cases that details feedstock R&D progress that occurred since FY13, resulting in modeled feedstock cost reductions of at least $63/ton and $23/ton for biochemical and thermochemical respectively, and total modeled delivered feedstock cost for each of $84/ton
  - The report will also detail modeled cost reductions and technology improvements in biomass harvest, collection, storage, transportation, and preprocessing. In collaboration with ANL, GHG emissions will be estimated using GREET and will be included in the final report delivered to BETO

GO/NO-GO DECISION POINT

- March 31, 2017: Determination of advanced feedstock supply systems as a viable option for meeting BETO cost, volume, and quality targets
  - Description: Compare AFSS to CFSS on a modeled cost:benefit basis including risk and reliability, to estimate the total modeled cost impacts and benefits of AFSS in decoupling feedstock supply from the conversion process and active quality management to improve the operability of the biorefinery, reduce variability and reduce risk

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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 and INL to guide R&D direction

ACCOMPLISHMENTS: Annual SOT tracking, significant new computational capabilities, initiation of analyses to find solutions to IBR reliability 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: IBR lessons learned have guided us toward quantifying the costs of operational reliability and supply risks in both CFSS and AFSS

Questions?

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Additional Slides

Responses to Previous Reviewers' Comments

- In the FY15 review of this project, it was noted that it seemed that our analysis has overlooked the current issues faced by the industry and focused more on the industry of the far future.
  - While it is true that much of our analysis is forward looking, this is important and necessary to lead to mobilizing the totality of sustainably available biomass identified in the latest Billion Ton study
  - Additionally, we have initiated analyses targeted toward quantifying the cost impacts of supply risk and operational reliability experienced by the current IBRs

- FY16 Go/No-go Decision Point (March 31, 2016)
  - Determination of advanced feedstock supply systems as a viable option for meeting BETO cost, volume, and quality targets by 2017 and 2022
  - To assess AFSS, the following criteria were applied:
    - Results from the Advanced Supply Systems Validation Workshop hosted by INL in 2015
    - Values added by AFSS, i.e., higher bulk density, consistent quality, better flowability … and the capability of those values to outweigh the cost associated with an advanced supply system in comparison to CFSS … because they are benefits to conversion facilities in terms of higher plant reliability and conversion yields.
    - The accessible resource mobilized using AFSS
  - BETO opted to "Defer Decision for Agreed-Upon Period" in lieu of analysis to quantify the cost of CFSS equipment unreliability due to feedstock physical properties.
    - This led to the current March 31, 2017 Go/No-go Decision Point

Publications

PUBLICATIONS

1. Jacobson, J.J., Roni, M.S., Cafferty, K., Kenney, K., Searcy, E., Hansen, J.K. (2014). Biomass feedstock supply system design and analysis. Idaho National Laboratory, Idaho Falls, Idaho, INL/EXT-14-33227.
2. Lamers, P., Roni, M.S., Tumuluru, J.S., Jacobson, J.J., Cafferty, K.G., Hansen, J.K., ..., Bals, B. (2015). Techno-economic analysis of decentralized biomass processing depots. *Bioresource Technology*, 194, 205-213.
3. Lamers, P., Tan, E.C., Searcy, E.M., Scarlata, C.J., Cafferty, K.G., Jacobson, J.J. (2015). Strategic supply system design–a holistic evaluation of operational and production cost for a biorefinery supply chain. *Biofuels, Bioproducts and Biorefining*, *9*(6), 648-660.
4. Searcy, E., Lamers, P., Hansen, J., Jacobson, J., Hess, J.R., Webb, E. (2015). Advanced Feedstock Supply System Validation Workshop Summary Report. Idaho National Laboratory, Idaho Falls, ID. INL/EXT-15-50315.
5. Roni, M., Eksioglu, S., Cafferty, K., Jacobson, J. (2016). A Multi-Objective, Hub-and-Spoke Model to Design and Manage Biofuel Supply Chains. *Annals of Operations Research*, DOI :10.1007/s10479-015-2102-3.
6. Owens, V.N., Karlen, D.L., Lacey, J. (2016). Regional Feedstock Partnership Report: Enabling the Billion-Ton Vision. Idaho National Laboratory, Idaho Falls, Idaho, INL/EXT-15-37477.
7. Roni, M., Cafferty, K., Hess, J., Jacobson, J., Searcy, E., Tumuluru, J. (2016). Lignocellulosic Crop Supply Chain. Biomass. *Biomass Supply Chains for Bioenergy and Biorefining*. Woodhead publishing series in energy.

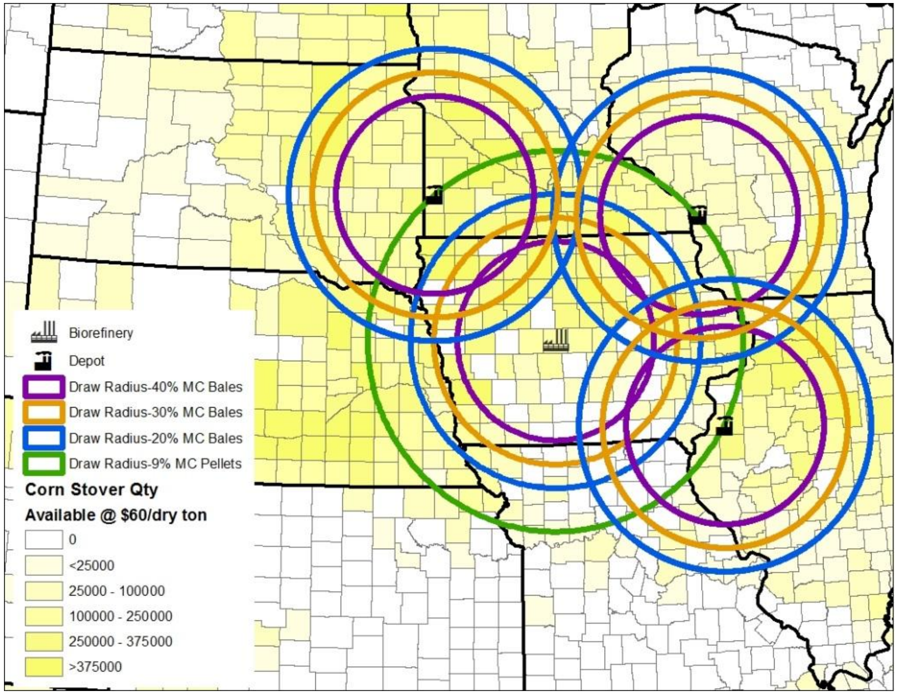
PUBLICATIONS SUPPORTED BY ANALYSIS FROM THIS PROJECT

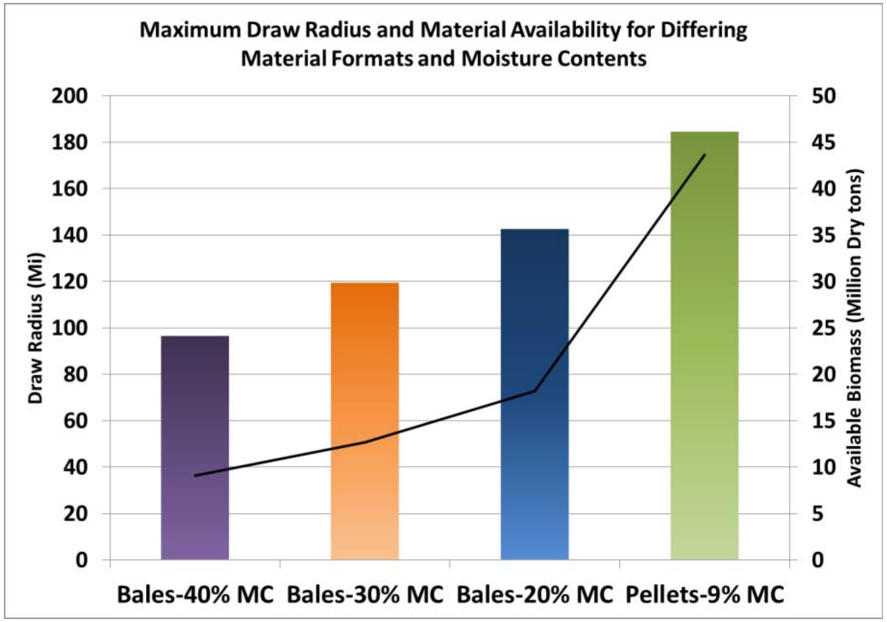
1. Thompson, V.S., Lacey, J.A., Hartley, D.S., Jindra, M.A., Aston, J.E., Thompson, D.N. (2016). Application of air classification and formulation to manage feedstock cost, quality and availability for bioenergy. *Fuel*, 180: 497-505.
2. Ray, A.E., Li, C., Thompson, V.S., Daubaras D.L., Nagel, N.J., Hartley, D.S. (2017). Biomass Blending and Densification: Impacts on Feedstock Supply and Biochemical Conversion Performance. In: *Biomass Volume Estimation and Valorization to Energy*, ISBN 978-953-51-4909-5.

Supporting Slides

3 – Technical Accomplishments (continued)

- CFSS rely on trucking to deliver baled feedstocks to central location
- Low density feedstock limits the sourcing radius—a supply system based solely on local resources has little resilience against supply interruptions
- Advanced systems can provide densified, conversion-ready feedstocks
- Quality is improved and variability is mitigated, reducing supply risk for the biorefinery





- *All supply radii assume use of truck transport only*
- *Use of rail transport, only economical with the pellets, would increase the maximum distance to a depot*

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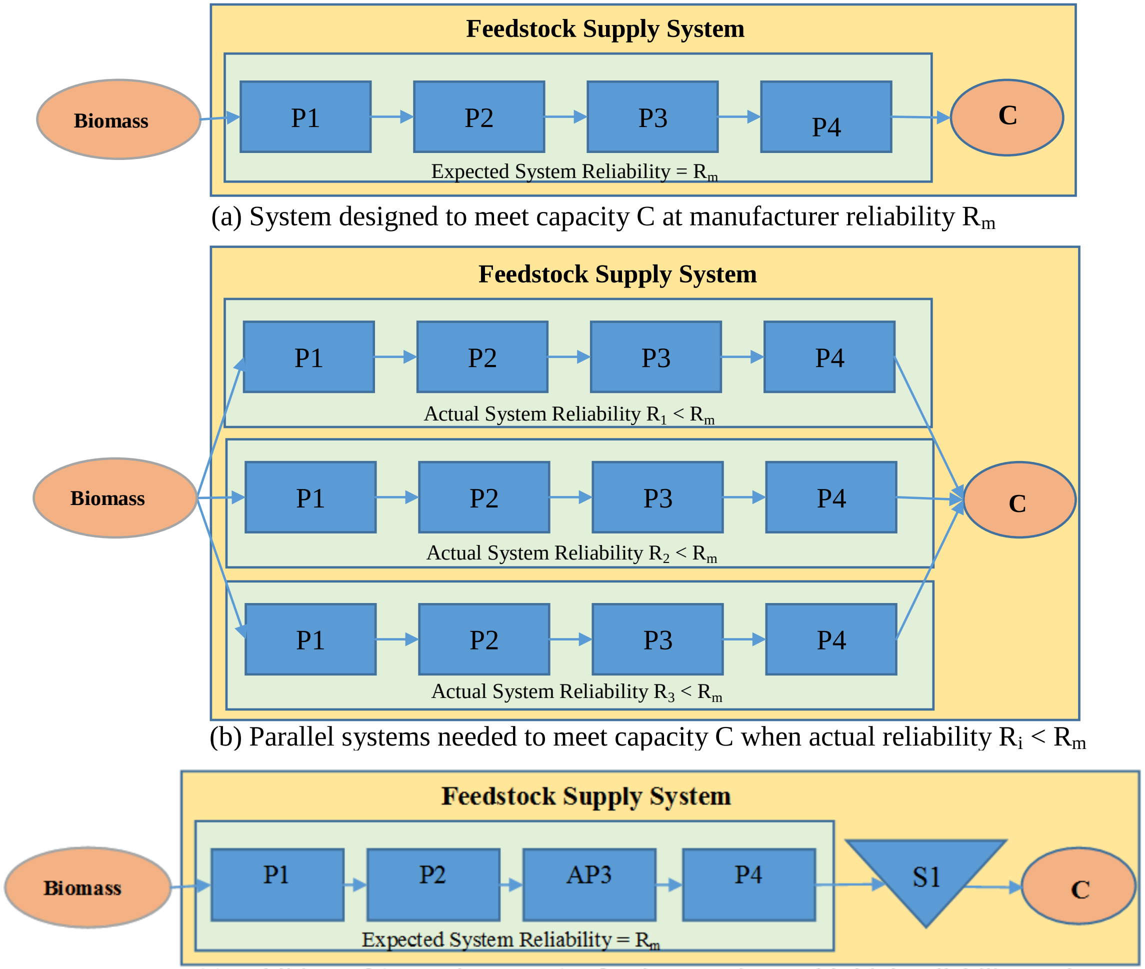
3 – Technical Accomplishments (continued)

- IBR Lessons Learned Guide Future Analysis
  - Feedstock handling difficulties at pioneer biorefineries leading to significant reduction in throughput versus design
  - Pioneer biorefineries now utilizing washing to remove soil ash (equipment wear issues)
- Analysis focus in FY17 is shifting to cost impacts of reliability

3 – Technical Accomplishments (continued)



(a) System designed to meet capacity C at manufacturer reliability R_m

(b) Parallel systems needed to meet capacity C when actual reliability $R_i < R_m$

(c) Addition of (or replacement) of unit operations with high reliability unit operations such as pelleting, and decoupling supply from biorefinery operation.

Modeling approach for cost of operational reliability as a function of feedstock properties

- Use manufacturer-defined reliability as highest reliability (MTTF & MTTR)
- Discrete event simulation to assess overall system reliability as a function of feedstock properties
  - Actual MTTF and MTTR guided by PDU and IBR experience
- Steady state process simulation using Aspen Plus to size the number of preprocessing trains needed to meet capacity

3 – Technical Accomplishments (continued)

Developing Feedstock Mobilization Success Indicators

SunShot Indicator	Analogous Feedstock Impact-Driven Indicator	Existing Analysis and Analysis Needed to Support Indicator
Achieving the SunShot price targets is projected to result in the cumulative installation of approximately 302 gigawatts (GW) of PV and 28 GW of CSP by 2030, and 632 GW of PV and 83 GW of CSP by 2050.	<u>*Mobilizing Biomass Resources*</u> Achieving the feedstock cost target of \$84.45/dry ton (2014\$) envisioned in the Advanced Feedstock Supply Systems (AFSS) scenario is projected to result in the mobilization of approximately 285 million tons of biomass by 2022 and 635 million tons[a] by 2040. This amounts to x% more biomass mobilized by 2022 and y% more by 2040 in the Conventional Feedstock Supply System (CFSS) reference scenario. *a This is 1 billion tons minus the amount already being utilized (BT16)*	<u>Partners:</u> • INL • ORNL <u>Analysis Gaps:</u> • Comprehensive analysis of AFSS versus CFSS for the entire period to 2040, accounting for the full set of metrics associated with cost, quality, convertibility, emissions, operational reliability, supply risk, fire risk, etc. <u>Current Analysis:</u> • 1.1.1.1… resource assessments • 1.1.1.2… supply system cost and reliability • 1.2.3.1… logistics costs • 4.1.2.20… supply chain risk

3 – Technical Accomplishments (continued)

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SunShot Indicator	Analogous Feedstock Impact-Driven Indicator	Existing Analysis and Analysis Needed to Support Indicator
Achieving the SunShot price targets is projected to result in the cumulative installation of approximately 302 gigawatts (GW) of PV and 28 GW of CSP by 2030, and 632 GW of PV and 83 GW of CSP by 2050.	<u>*Mobilizing Biomass Resources*</u> Achieving the feedstock cost target of \$84.45/dry ton (2014\$) envisioned in the Advanced Feedstock Supply Systems (AFSS) scenario is projected to result in the mobilization of approximately 285 million tons of biomass by 2022 and 635 million tons[a] by 2040. This amounts to x% more biomass mobilized by 2022 and y% more by 2040 in the Conventional Feedstock Supply System (CFSS) reference scenario. *a This is 1 billion tons minus the amount already being utilized (BT16)*	<u>Partners:</u> • INL • ORNL <u>Analysis Gaps:</u> • Comprehensive analysis of AFSS versus CFSS for the entire period to 2040, accounting for the full set of metrics associated with cost, quality, convertibility, emissions, operational reliability, supply risk, fire risk, etc. <u>Current Analysis:</u> • 1.1.1.1…resource assessments • 1.1.1.2…supply system cost and reliability • 1.2.3.1…logistics costs • 4.1.2.20…supply chain risk
Achieving the level of price reductions envisioned in the SunShot Initiative could result in solar meeting 14% of U.S. electricity needs by 2030 and 27% by 2050. However, realizing these price and installation targets will require a combination of evolutionary and revolutionary technological changes.	<u>*Displacing Foreign Oil*</u> Achieving the level of feedstock price reductions envisioned in the AFSS scenario could result in drop-in biofuels meeting x% of U.S. fuel needs by 2022 and y% by 2040. This amounts to m% more drop-in biofuels produced by 2022 and n% more by 2040 in the CFSS reference scenario. However, realizing these price and installation targets will require a combination of evolutionary and revolutionary technological changes across the entire feedstock supply chain.	<u>Partners:</u> • INL • ORNL • NREL • PNNL <u>Analysis Gaps:</u> • Same as above • This is a calculation from the resource numbers above, and requires convertibility testing of blends by the conversion projects <u>Current Analysis (include WBS):</u> • Same as above

3 – Technical Accomplishments (continued)

Developing Feedstock Mobilization Success Indicators

SunShot Indicator	Analogous Feedstock Impact-Driven Indicator	Existing Analysis and Analysis Needed to Support Indicator
Both the SunShot and reference scenarios require significant transmission expansion. In the reference scenario, transmission is expanded primarily to meet growing electricity demand by developing new conventional and wind resources. In the SunShot scenario, transmission is expanded at a similar level, but in different locations in order to develop solar resources. Achieving the SunShot scenario level of solar deployment could support 290,000 new solar jobs by 2030, and 390,000 new solar jobs by 2050.	*Building the US and Rural Economies* Both the AFSS and CFSS reference scenarios require significant expansion of the harvest, collection, transportation and preprocessing equipment manufacturing capacity. Achieving the AFSS scenario level of drop-in biofuels deployment could support x new manufacturing jobs by 2022, and y new manufacturing jobs by 2040. This amounts to m% more manufacturing jobs created by 2022 and n% more by 2040 in the CFSS reference scenario. Similarly, significant expansion of the labor force to operate this new equipment will be required. Achieving the AFSS scenario level of drop-in biofuels deployment could support x new rural jobs by 2022, and y new rural jobs by 2040. This amounts to m% more rural jobs created by 2022 and n% more by 2040 in the CFSS reference scenario.	Partners: • INL • NREL • NREL SI Analysis Gaps: • Impact is regional and supply chain specific; additional case studies (JEDI, BSM) are needed to derive an estimate of national impact for both CFSS and AFSS Current Analysis (include WBS): • 6.3.0.10…CEMAC will estimate the expansion of manufacturing from biomass mobilization with both CFSS and AFSS, as well as inform how and when the manufacturing industry will respond and the market drivers

3 – Technical Accomplishments (continued)

Developing Feedstock Mobilization Success Indicators

SunShot Indicator	Analogous Feedstock Impact-Driven Indicator	Existing Analysis and Analysis Needed to Support Indicator
The level of solar deployment envisioned in the SunShot scenario poses significant but not insurmountable technical challenges with respect to grid integration and could require substantial changes to system planning and operation practices.	<u>*Partnering with Industry*</u> The level of biomass mobilization envisioned in the AFSS scenario poses significant technical challenges to establishing quality requirements for successfully converting the biomass resources to drop-in biofuels, and could require substantial changes to system integration planning and operational practices at the conversion facility.	<u>Partners:</u> • INL • NREL • PNNL • BETO DMT • Industry <u>Analysis Gaps:</u> • Grading criteria; integration of feedstock supply and conversion technoeconomic models <u>Current Analysis (include WBS):</u> • 2.2.1.501…characterization and grading • Supported by 2.2.1.101-10x and 2.2.1.301-30x
The land area that is potentially suitable for solar deployment is enormous and thus land, per se, is not a constraint on meeting the SunShot scenario level of deployment. However, it is important to make careful selection of sites in order to provide access to available or planned transmission, and to minimize conflicts with environmental, cultural, and aesthetic interests. Water-use constraints will require CSP technologies to transition away from wet cooling toward dry and hybrid cooling.	<u>*Feedstock Commoditization*</u> The resource base is sufficient to support the level of resource mobilization envisioned in the AFSS scenario. However, available infrastructure, utilities, labor, market outlets, etc. may limit biorefinery siting to co-location with available resources. Commoditization of feedstocks alleviates this issue, but imposes additional technical, regulatory, and market drivers required to achieve the biomass mobilization scenario.	<u>Partners:</u> • INL • NREL SI • IEA Task 40 <u>Analysis Gaps:</u> • Understanding what the technical, regulatory, and market drivers are that will be required to enable commoditization of biomass • Understanding the drivers to biomass transactions in trade <u>Current Analysis (include WBS):</u> • 1.2.1.5…trade flows

3 – Technical Accomplishments (continued)

Developing Feedstock Mobilization Success Indicators

SunShot Indicator	Analogous Feedstock Impact-Driven Indicator	Existing Analysis and Analysis Needed to Support Indicator
Financing the scale of expansion in the SunShot scenario will require significant new investments in the solar manufacturing supply chain and in solar energy projects.	*Feedstock Production* Financing the scale of feedstock supply expansion in the AFSS scenario will require significant new investments in the biomass harvest, collection, transportation and preprocessing equipment manufacturing capacities and in biomass feedstock production projects.	Partners: • INL • NREL • NREL SI Analysis Gaps: • Impact is regional and supply chain specific; additional case studies (JEDI, BSM) are needed to derive an estimate of national impact for both CFSS and AFSS Current Analysis (include WBS): • 6.3.0.10…CEMAC will estimate the expansion of manufacturing from biomass mobilization with both CFSS and AFSS, as well as inform how and when the manufacturing industry will respond and the market drivers
Sensitivity analyses indicate that a number of factors could influence the level of solar deployment envisioned in the SunShot scenario, including more aggressive cost reductions in other renewable and conventional electricity-generation technologies, fossil fuel prices, electricity demand growth, and other assumptions.	*Cross-Cutting Industry Impacts* A number of factors could influence the level of biomass mobilization envisioned in the AFSS scenario, including competition for biomass supplies, biofuel price competition with fossil energy sources, and with high value co-products of biofuel production.	Partners: • INL • NREL • NREL SI • PNNL Analysis Gaps: • Understanding the role of aggregating and cascading markets and how they enable and/or compete with biofuels for biomass supplies Current Analysis (include WBS): • 1.2.1.5 and BSM…market push • 3.5.1.5…companion markets

3 – Technical Accomplishments (continued)

Developing Feedstock Mobilization Success Indicators

SunShot Indicator	Analogous Feedstock Impact-Driven Indicator	Existing Analysis and Analysis Needed to Support Indicator
Siting poses significant, but not insurmountable, regulatory challenges to achieving the level of solar market penetration envisioned in the SunShot scenario.	*Policy and Regulatory Challenges* Achieving the AFSS scenario level of biomass mobilization poses significant, but not insurmountable policy and regulatory challenges to achieving the level of energy crop production and utilization of waste resources envisioned.	Partners: • INL • ORNL • USDA • Universities Analysis Gaps: • Analysis of land use change, water use, nutrient accumulation in lakes and rivers, invasive species • Pathway qualification for RINS Current Analysis (include WBS): • None
Achieving the SunShot scenario level of solar deployment would result in significant downward pressure on retail electricity prices.	*Biomass Supply /Demand Dynamics* Achieving the AFSS scenario level of biomass mobilization by 2040 cannot be achieved solely by technology advancements that reduce delivered cost and in effect increase biomass supply. Technology advancements are also needed that add more value to the supply chain, thereby increasing demand.	Partners: • INL • NREL • NREL SI • PNNL Analysis Gaps: • Understanding the role of aggregating and cascading markets and how they enable and/or compete with biofuels for biomass supplies Current Analysis (include WBS): • 1.2.1.5 and BSM…market push • 3.5.1.5…companion markets