DOE Bioenergy Technologies Office 2019 Project Peer Review

Economic Analysis of Risk
WBS# 4.1.2.20

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Analysis & Sustainability

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Goal Statement

- Tackling one aspect of risk, and taking a quantitative, economic approach, the goal of this project is to enhance understanding of cost risk in the biomass feedstock supply chain while at the same time increasing the fidelity of cost risk estimating capability available to analysts in feedstock supply and logistics.

- The Stochastic Techno-Economic Model (STEM) simulates possible cost outcomes from which cost risk can be quantified, which supports reducing risks and costs associated with biomass feedstock. (Ft-A)

- The STEM enables system level analysis of costs risk, and supports cost-benefit (cost vs. risk-reduction) studies. (At-B, At-E)

Quad Chart Overview

Timeline

- Project start date 10/01/2015
- Project end date 09/30/2018
- Percent complete 100%

Budget

	pre-FY 17 Costs	FY17 Costs	FY18 Costs	Total Funding
DOE Funded	$259k	$300k	$245k	$804k

Objective

- Improve the analytical capability to quantify cost-risk in the biomass feedstock supply chain.

Barriers

- At-B: Analytical tools and capabilities for system-level analysis
- At-E: Quantification of economic, environmental, and other benefits and costs
- Ft-A: Feedstock availability and cost

End of Project Goal

- Enhance understanding of cost-risk in the biomass feedstock supply chain and increase the fidelity of cost-risk estimating capability.

1 – Project Overview

- Stakeholder engagement in the cellulosic industry, and the literature on biomass development, find that feedstock risks are a key impediment to industry growth (Searcy et al. 2015; Babcock, Marette et al. 2011; Kenkel and Holcomb 2009; Gustafson 2008).
  - Clear need to identify and reduce risk to growers, biorefineries and equipment manufacturers; risks are distributed across the supply chain.
  - Feedstock supply system risks must be managed or mitigated.
  - Bio-refining is in its infancy, the lack of historical data increases perceived investor risks, amplifies the need for a quantitative, simulation-based approach.
- STEM solves one piece of the risk – the missing data problem – by focusing on cost risk between the field and the biorefinery. Developed based on supply chain configurations in technology reports, STEM simulates possible outcomes for the feedstock logistics cost.

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2 – Approach (Management)

- STEM is an analysis tool that requires input data from, and generates risk assessment for, projects related to feedstock supply chains.
  - 1.1.1.2 Feedstock Supply Chain SOT (slide 6,7)
    - Cost data on herbaceous, woody, and blended feedstocks (BLM)
    - Risk assessment for 2013 and 2017 SOT cases
  - 1.2.2.2 Biomass Feedstock Library, Risk Standards and Certification
    - Economic model to generate input for use in certification framework
  - 4.2.2.62 Enabling Sustainable Landscape Design
    - Cost data from Antares Group for switchgrass and corn stover production
    - Risk assessment for 2018 logistics cost analysis

- STEM is made possible because of collaboration of an interdisciplinary team of experts; complementary fields are represented.
  - Feedstock logistics cost, ag engineering, operations research (INL: M. Roni, D. Hartley)
  - Uncertainty modeling and risk analysis (INL: S. Nair, J. Hansen, P. Burli; Purdue: X. Zhao; UNM: S. Mamun)
  - Computer science and model interface (INL: M. Griffel, V. Vazhnik)

2 – Approach (Management) STEM – Inputs

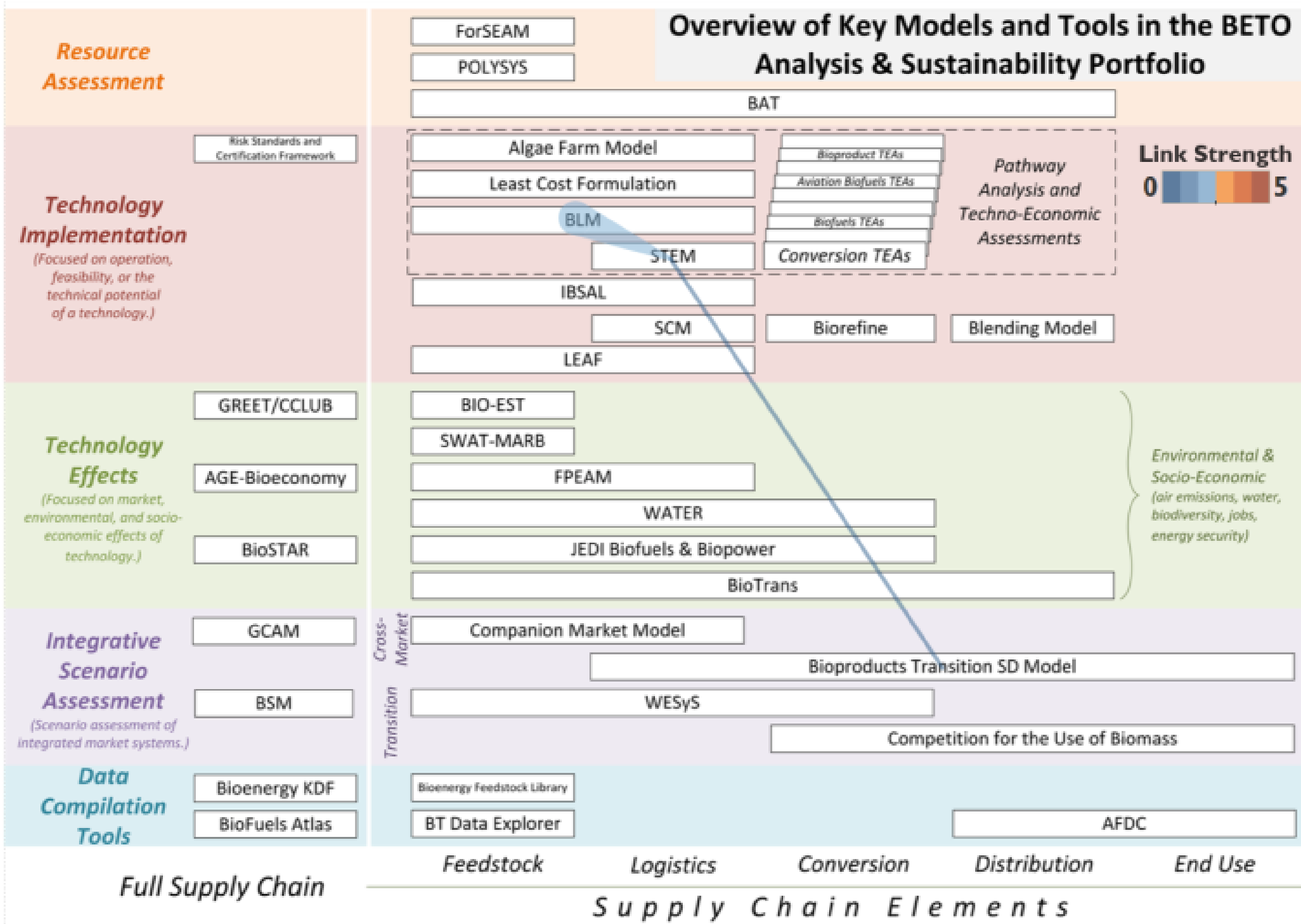


Figure credit: NREL, model mapping

2 – Approach (Management) STEM – Outputs

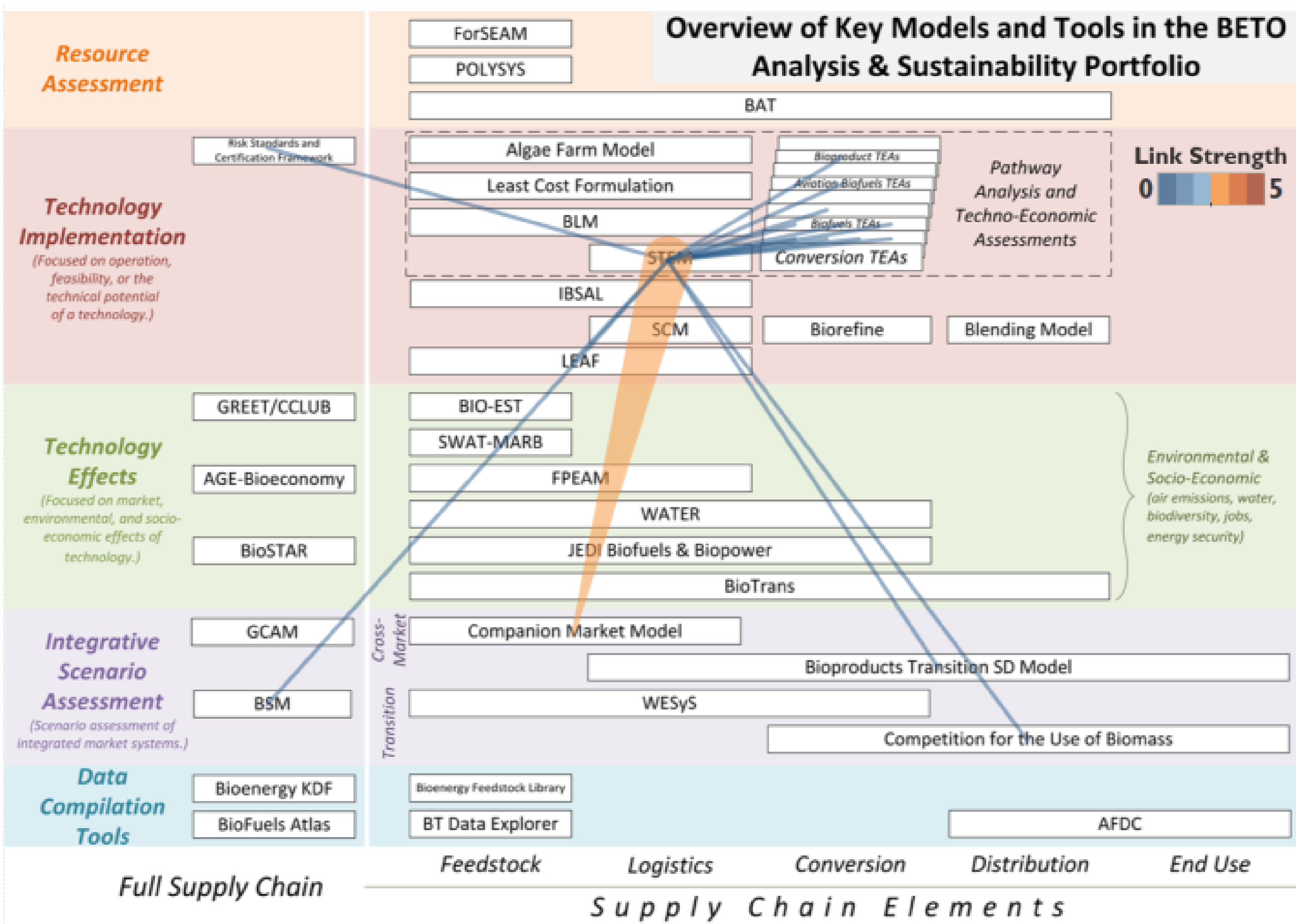


Figure credit: NREL, model mapping

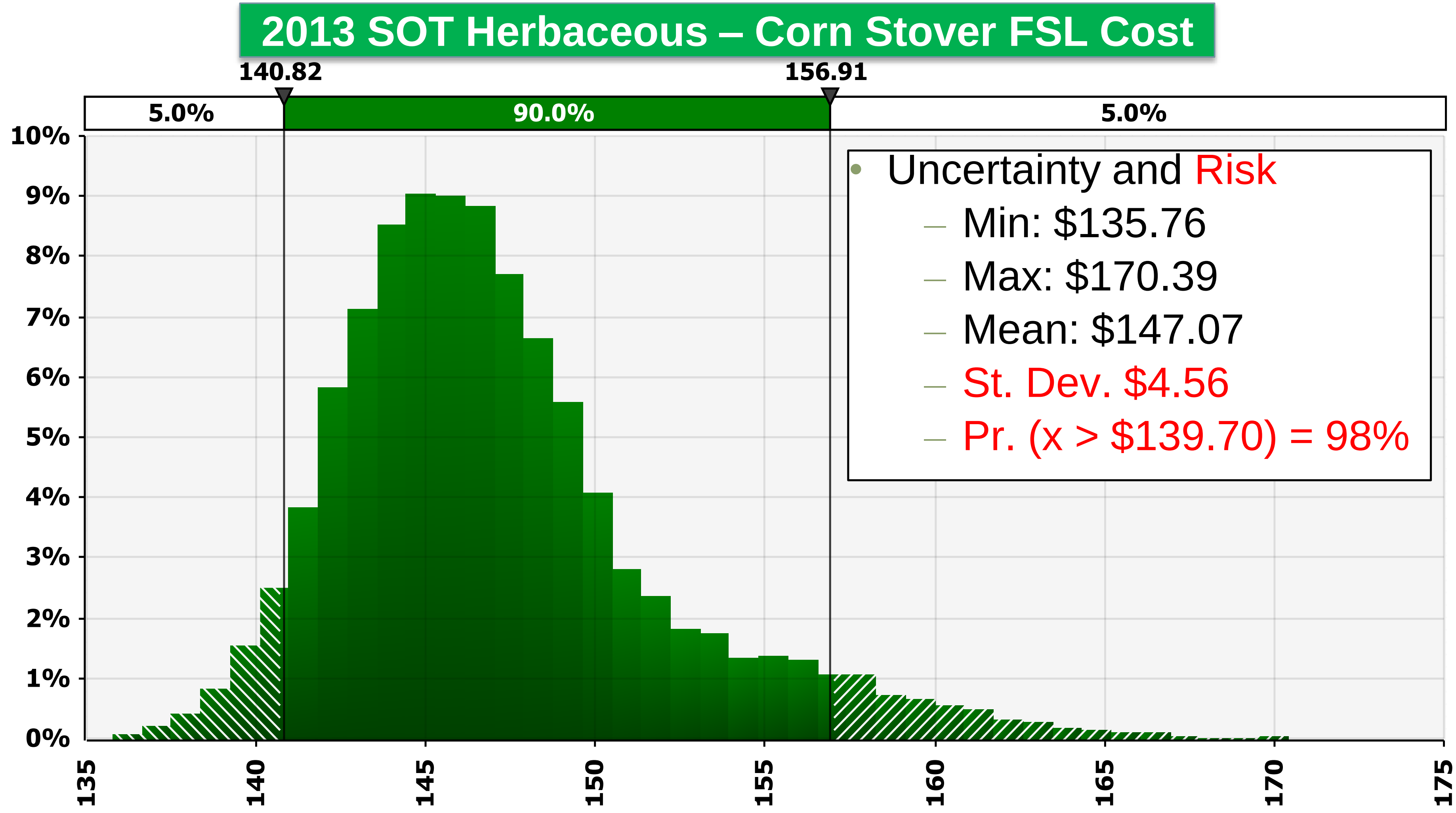
2 – Approach (Technical)

- Perform case study quantifying supply chain risk based on uncertainty in preprocessing. Milestone (9/30/16)
  - Follow best practices of cost risk assessment (Ashley, 2013)
  - Literature search on appropriate uncertainty models
  - Propagate uncertainty into cost elements in preprocessing, input cost data from BLM
- Propagate uncertainty to unit operations of storage and transportation. Go/No-Go (3/30/17)
  - Verify that modeling approach can be extended to additional unit operations of the supply chain
  - Present analysis to BETO staff
- Perform cost risk assessment on at least two additional supply chain configurations. Milestone (6/30/18)
  - Enabling Integrated Landscape, switchgrass and corn stover for study site
  - 2017 SOT, blended feedstock: corn stover, switchgrass, MSW (grass clippings)

2 – Approach (Technical)

- Success Factors
  - Improved state of knowledge on cost-risk in bioenergy feedstock supply
    - Assessments on alternative supply chain configurations
    - Publications that describe assessment outcomes
    - Demonstrating how risks change across configurations
    - Sensitivity analyses that inform on risk-mitigating options
  - A downloadable, cost-risk assessment model (STEM), with instructional guide and example case studies
    - Available for analysts interested in biomass feedstock supply
    - Enables cost-benefit analysis (in terms of risk reduction)
- Key Challenges
  - Arriving at the best way for interested analysts to access STEM
    - User interface vs. model download
    - ‘Canned cases’ vs. allowing users to input own data
    - Maintaining model fidelity
  - Disseminating results of case studies

3 – Technical Results (Herbaceous Feedstocks)

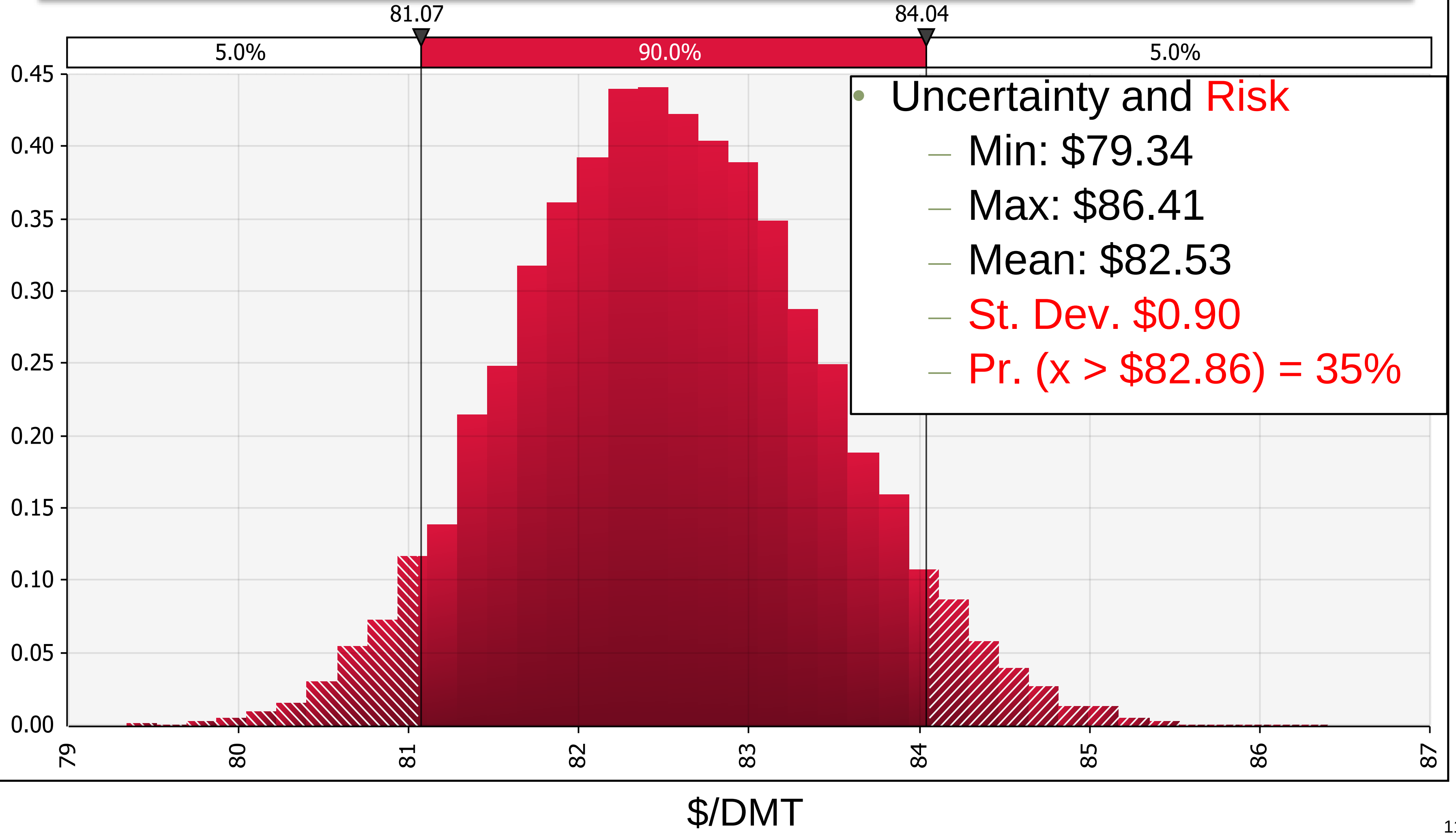


- Uncertainty and Risk
  - Min: $135.76
  - Max: $170.39
  - Mean: $147.07
  - St. Dev. $4.56
  - Pr. (x > $139.70) = 98%

$/DMT

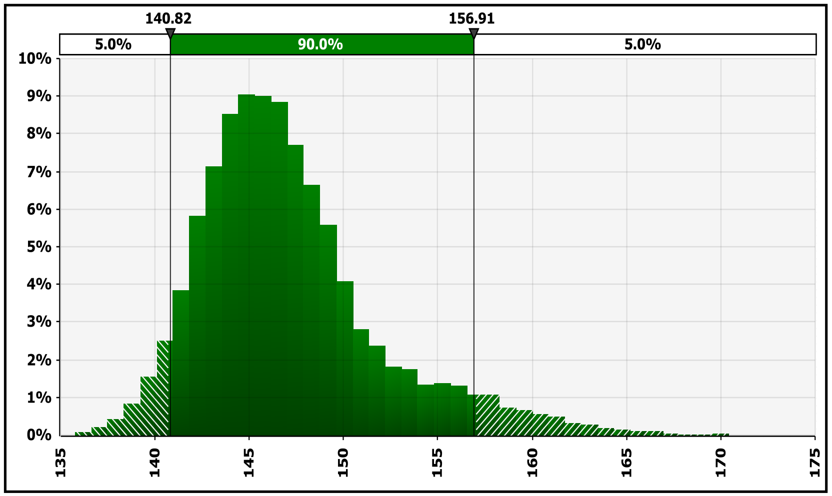
3 – Technical Results (Herbaceous Feedstocks)

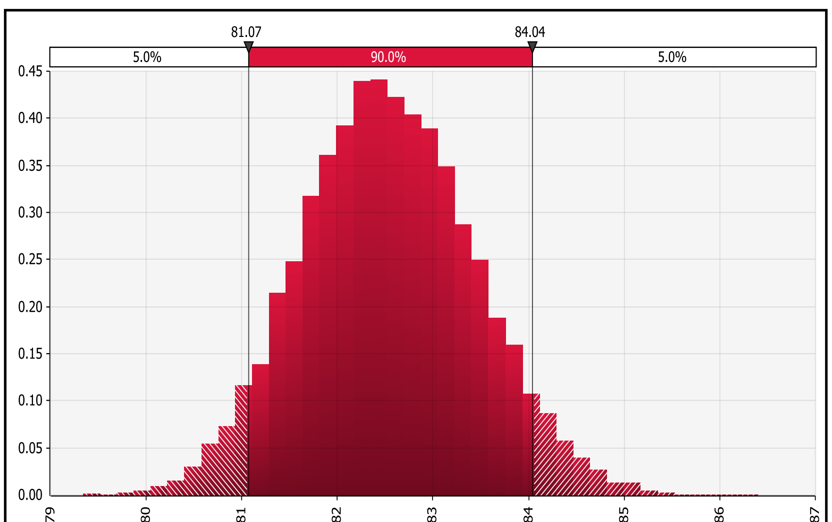
2017 SOT Herbaceous – Blend of Switchgrass, Corn Stover, MSW



- Uncertainty and Risk
  - Min: $79.34
  - Max: $86.41
  - Mean: $82.53
  - St. Dev. $0.90
  - Pr. (x > $82.86) = 35%

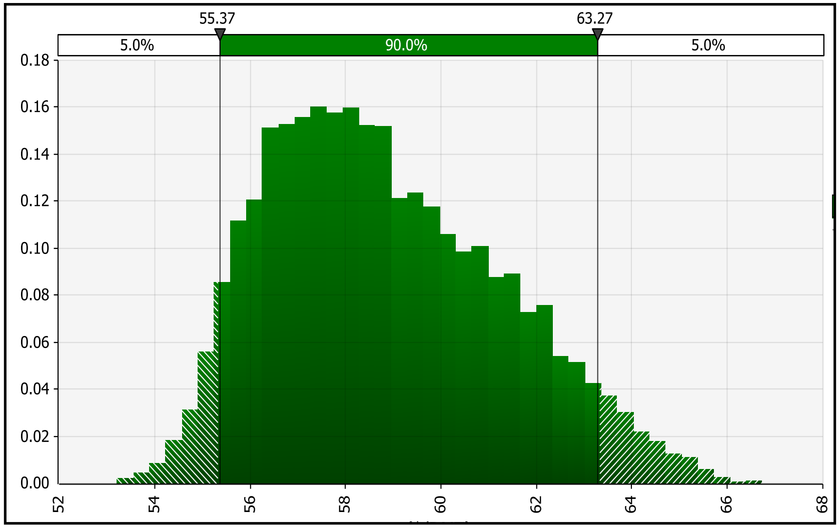
3 – Technical Results (Herbaceous Feedstocks)
comparing supply chains based on cost-risk

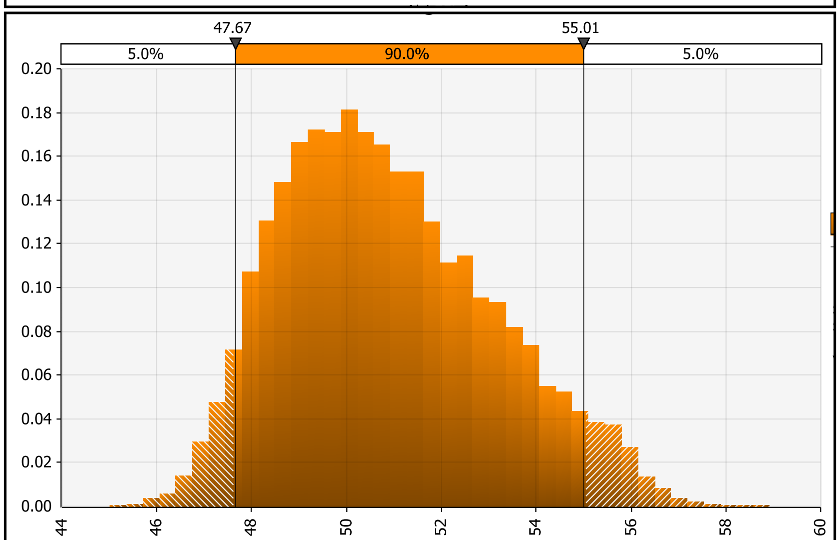




- Results from application to SOT (WBS# 1.1.1.2)
- Less uncertainty in red histogram
  - More narrow "shape"
  - Smaller range (slide 10,11)
  - Smaller standard deviation
- Less risk shown in red histogram
  - Relative to deterministic estimate, less chance for cost overrun (slide 10,11)
  - Less variation means greater fidelity in cost estimate
- Cost-risk assessment provides additional dimension of comparison, improves economic understanding of the system.

3 – Technical Results (Landscape Design)
comparing two feedstocks in LD on cost-risk

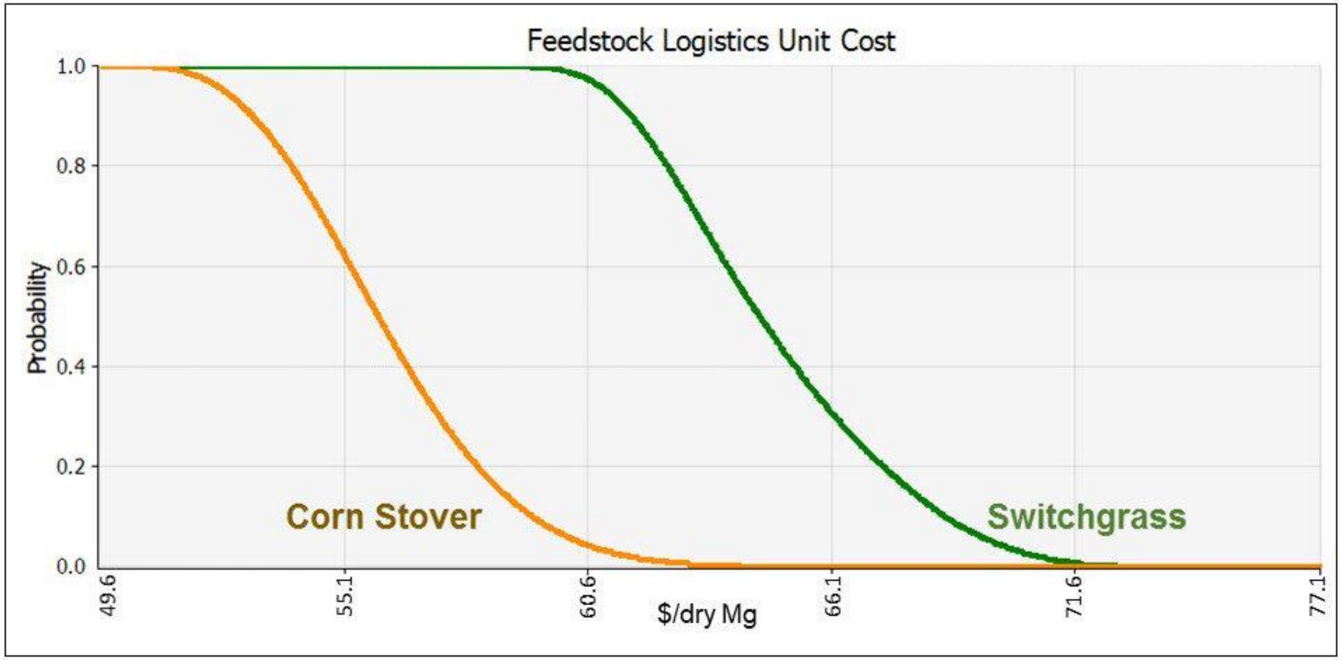




$/DMT	Switchgrass	Corn Stover
Min:	53.22	45.01
Max:	66.73	58.93
Mean $\bar{X}$:	58.84	49.48
St. Dev:	2.45	2.23
Pr. $(x > \bar{X})$	73%	70%

- Results from application to LD (WBS# 4.2.2.62).
- Modeling results suggest slightly greater cost risk in production of switchgrass.
- Cost-risk assessment establishes a baseline, reference point of comparison for future configurations.

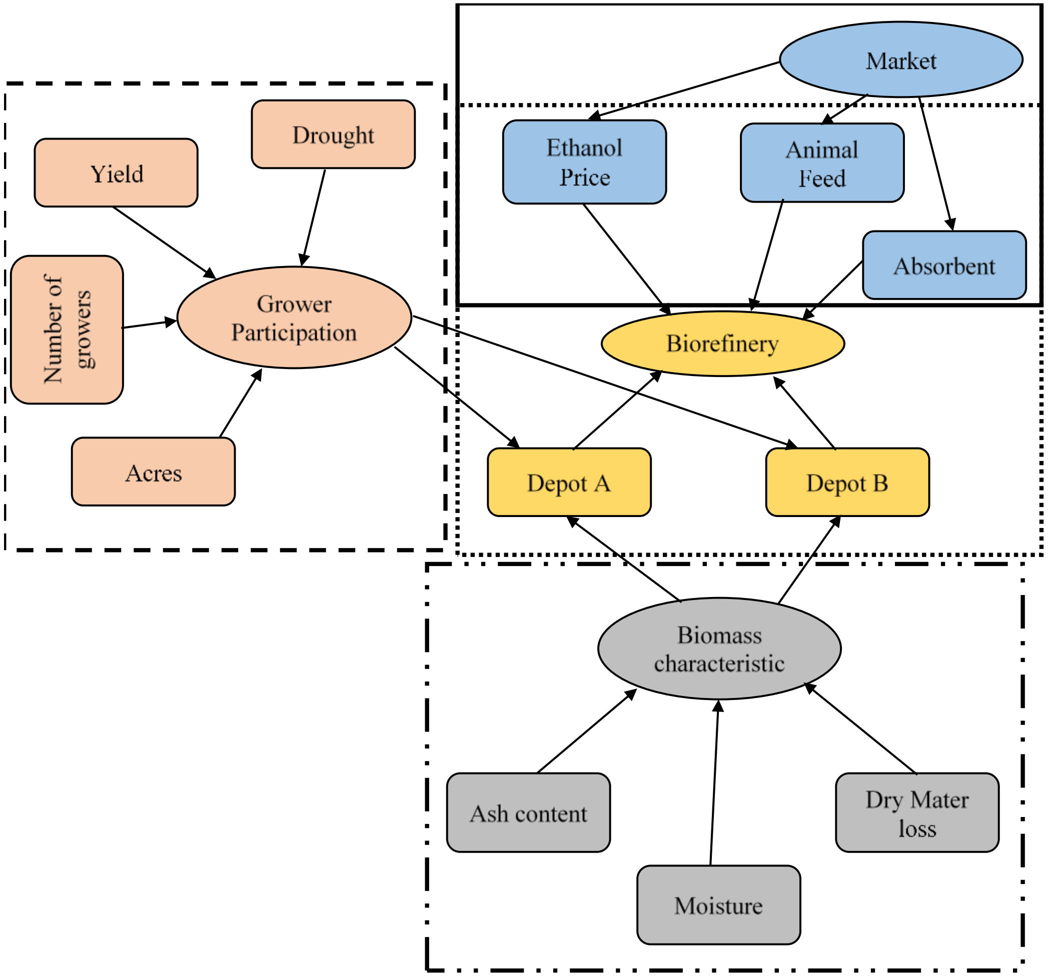
3 – Technical Results (Manuscript Submitted)
"Herbaceous feedstock supply chain cost risk assessment"



- Manuscript documents the approach to cost estimating and companion cost-risk assessment, study locations, and sensitivities.
- Uncertainty in harvest and collection was a large driver in uncertainty represented in the figure above.
- Manuscript submitted to: *Biomass and Bioenergy*

3 – Technical Results (Manuscript Submitted)

"Managing risk at the cellulosic biorefinery"



- Which approach is best suited to managing risk depends on the types of risks in the system.
- Supply risk, operational risk and market risk impact economic performance of the biorefinery.
- This study models uncertainty from key components in the feedstock supply system, and translates it to these three types of risk.
- Investigates how technology enables risk reduction and mitigation.

3 – Technical Results (Manuscript Submitted)

"Managing risk at the cellulosic biorefinery"

Scenario	Risk	Risk value	Parameter	Measure	Mean value	Standard deviation
CFSS Baseline	Supply	48.9	Q	Q<700000 DMT	697,391.43	266,535.96
	Operational	75.5	MFSP	MFSP > $3.17	$4.39	$2.97
	Market	71	ROI	ROI < 10%	-8.06%	35.33%
CFSS OVRCNTRCT	Supply	27.8	Q	Q<700000 DMT	932,302.22	356,316.49
	Operational	82.5	MFSP	MFSP > $3.17	$3.96	$1.91
	Market	70	ROI	ROI < 10%	-4.87%	32.51%
AFSS Baseline	Supply	54	Q	Q<700000 DMT	692602.45	128,636.51
	Operational	91.5	MFSP	MFSP > $3.17	$3.69	$0.52
	Market	71.3	ROI	ROI < 10%	-3.87%	29.24%
AFSS OVRCNTRCT	Supply	6	Q	Q<700000 DMT	998212.90	200,872.76
	Operational	97.1	MFSP	MFSP > $3.17	$3.73	$0.41
	Market	73.5	ROI	ROI < 10%	-5.53%	27.80%
AFSS Baseline, Animal Feed mkt	Supply	54	Q	Q<700000 DMT	692,602.45	128,636.51
	Operational	74	MFSP	MFSP > $3.17	$3.57	$0.59
	Market	66.3	ROI	ROI < 10%	0.20%	31.77%
AFSS OVRCNTRCT, , Animal Feed mkt	Supply	6	Q	Q<700000 DMT	998,212.90	200,872.76
	Operational	22.6	MFSP	MFSP > $3.17	$2.77	$0.60
	Market	36	ROI	ROI < 10%	33.01%	52.12%
AFSS Baseline	Supply	54	Q	Q<700000 DMT	692,602.45	128,636.51
	Operational	22	MFSP	MFSP > $3.17	$3.60	$0.57
	Market	67.6	ROI	ROI < 10%	-0.96%	30.81%
AFSS OVRCNTRCT, Absorbent mkt	Supply	6	Q	Q<700000 DMT	998,212.90	200,872.76
	Operational	30.5	MFSP	MFSP > $3.17	$3.01	$0.47
	Market	45	ROI	ROI < 10%	18.65%	37.57%
AFSS Baseline	Supply	54	Q	Q<700000 DMT	692,602.45	128,636.51
	Operational	26	MFSP	MFSP > $3.17	$3.57	$0.60
	Market	66.3	ROI	ROI < 10%	0.20%	31.77%
AFSS OVRCNTRCT, Alternate mkt	Supply	6	Q	Q<700000 DMT	998,212.90	200,872.76
	Operational	22.6	MFSP	MFSP > $3.17	$2.77	$0.60
	Market	36	ROI	ROI < 10%	33.02%	52.12%

CFSS: Conventional Supply Chain
AFSS: Advanced Supply Chain

- Analysis considered supply chain configurations based on two technology options: conventional and advanced.
- Considered operational strategy to over-contract, and market strategy to diversify product offerings.
- Simulation model shows improvements in
  - Operational Risk (MFSP)
    - $4.39 to $2.77
  - Market Risk (ROI)
    - -8% to 33%

3 – Technical Results (Published Study)

Applied Energy 222 (2018) 621–636

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Making money from waste: The economic viability of producing biogas and biomethane in the Idaho dairy industry

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HIGHLIGHTS

- Anaerobic digestion can increase the income of (dairy) farmers.
- ≥3000 cows per farm are required for an economically viable plant operation.
- Joint, cooperative anaerobic digestion plants allows a higher manure utilization.

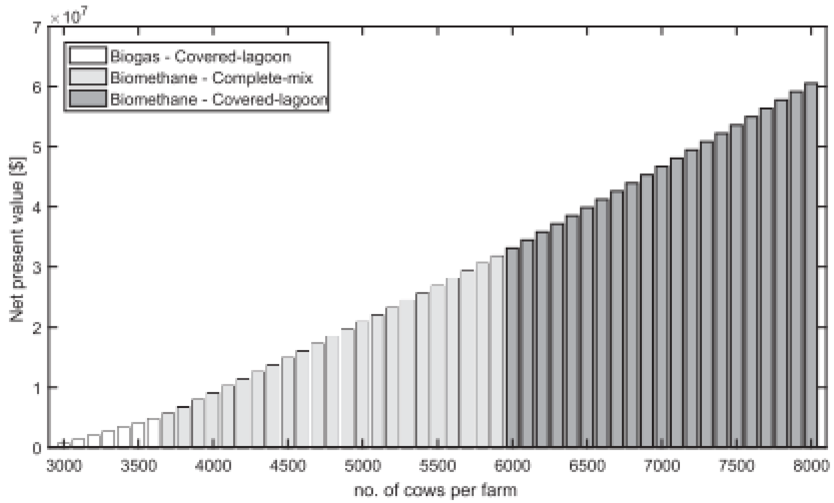

Fig. 6. Combination of biogas and biomethane use characterized by the highest NPV depending on the number of cows per farm.

- Collaborative effort enabled through IEA Bioenergy.
- Applied techno-economic approach to production of biogas and bioenergy from dairy waste with three technology configurations.
- Estimated economic viability for Idaho dairy producers and environmental benefits.
- Lauer, M., Hansen, J. K., Lamers, P., & Thran, D. (2018). Making money from waste: The economic viability of producing biogas and biomethane in the Idaho dairy industry. *Applied Energy, 222*, 621-636.

4 – Relevance

To BETO:

- This project develops a capability that enhances understanding of cost risk in biomass feedstock supply, and generates information that can be used in systems analysis. (At-B)
- It enables cost-benefit analysis (cost vs. risk-reduction) in feedstock logistics, which supports identifying promising, economically viable supply chain configurations. (At-E)
- The project facilitates strategies to reduce feedstock cost through risk reduction. (Ft-A)

To analysts interested in biomass supply:

- STEM enables cost risk analysis across supply chain configurations, and supports identifying strategies to reduce and mitigate risk.
- STEM can be used to compute the risk premiums necessary to price risk for feedstock supply chain investments, replacing <u>perceived</u> risks with <u>quantified</u> risks.

Summary

- This is a sun-setting projecting, which finished up its third year at the end of the last fiscal year. It supports BETO goals of reducing risk and improving analysis in bioenergy through capability development and documenting case studies.
- Economic risks in biomass feedstock supply are known risks, by stakeholders and researchers alike, that have to be overcome for industry success.
- To quantify cost risk, researchers followed best practices from the literature on cost estimating and risk assessment, leveraging existing framework for cost estimating and independently assessing cost risk.
- Researchers developed a model, STEM, to quantify cost risk in feedstock supply and quantified cost risk in reports on current state of technology (SOT), and in landscape design configurations.
- In the analysis comparing two SOT cases, researchers found that a blended feedstock results in less cost risk than a traditional, corn stover case. In analysis on landscape design, researchers found switchgrass holds more cost risk than corn stover.
- A pending publication documents the cost risk assessment for integrated landscape design; another assesses operational, market risk, and strategies of diversification and mitigation.
- Project model will be publicly available, pending INL release.

Appendix Slides

Responses to Previous Reviewers' Comments

- Management plan/technical approach for task B, stochastic techno-economic modeling (STEM), is clear. Biofuel supply chain will based on 2017 SOT reports from INL. The methods should be updated to incorporate new information from other projects and/or new SOT reports released.

  Since the last peer review, project plans included applying STEM to a case of integrated landscape design. The manuscript submitted for publication and the results shown in this presentation come from that work. The reviewers' comments impacted project planning and directions of analysis.

- The list of publications and presentations at the end of the presentation could be improved. Two of the presentations are "internal" to the BETO program, one is to an economic development club at a local university, and one is to the system dynamics modeling community. The project should focus on how this publication record will be improved as the project moves forward.

  Project researchers worked to improve the publication record from this project. The list now includes manuscripts submitted for publication, presentations at universities specializing in risk analysis, and a publication in an energy journal.

Publications and Presentations***

- Hansen, J.K, Nair, S.K., Roni, M.S., Hartley, D.S., Griffel, L.M., Vazhnik, V. & Mamun, S. Herbaceous feedstock supply chain cost risk assessment. Submission to *Biomass and Bioenergy.**
- Mamun, S., Hansen, J.K., Searcy, E.M., & Jacobson, J. Managing risk at the cellulosic biorefinery. Submission to *Renewable & Sustainable Energy Reviews*.*
- Lauer, M., Hansen, J., Lamers, P, & Thran, D. (2018). Making money from waste: the economic viability of producing biogas and biomethane in the Idaho dairy industry. *Applied Energy,* 222, 621-636. doi:10.1016/j.apenergy.2018.04.026*
- Hansen, J. (2018). Quantifying cost risk in the biofuel supply chain due to feedstock logistics. *Presented at* Department of Agricultural Economics, Utah State University, Logan UT, April 25.**
- Hansen, J. (2017). Building the cellulosic industry through risk analysis and integrated landscape management. *Presentation in* the Department of Economics Seminar Series, University of New Mexico, Albuquerque, NM, March 24.**
- Hansen, J. & Nair, S. (2016). The economic analysis of risk. *Presentation to* BETO A&S Special Topics Presentation, webinar originating at Idaho National Laboratory, November 7.**
- Hansen, J. (2016). Risk analysis in the bioenergy feedstock supply chain. *Presented to* the Economics Club at Idaho State University, Pocatello, ID, October 12.**
- Hansen, J.K., & Nair, S.K. (2016). Brief Overview of Feedstock Supply Chain Risk Assessment and Integrated Landscape Management. *Presented at* Bioenergy Supply-Chain Modeling Workshop, National Renewable Energy Laboratory, Golden, CO, June 29 – 30.**
- Hansen, J., Jacobson, J., Roni, M. (2015). Quantifying Supply Risk at a Cellulosic Biorefinery. In K. Chichakly, & K. Saeed (Eds.), *Proceedings from the 33rd International Conference of the System Dynamics Society.* Albany, New York: System Dynamics Society.*


INL
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