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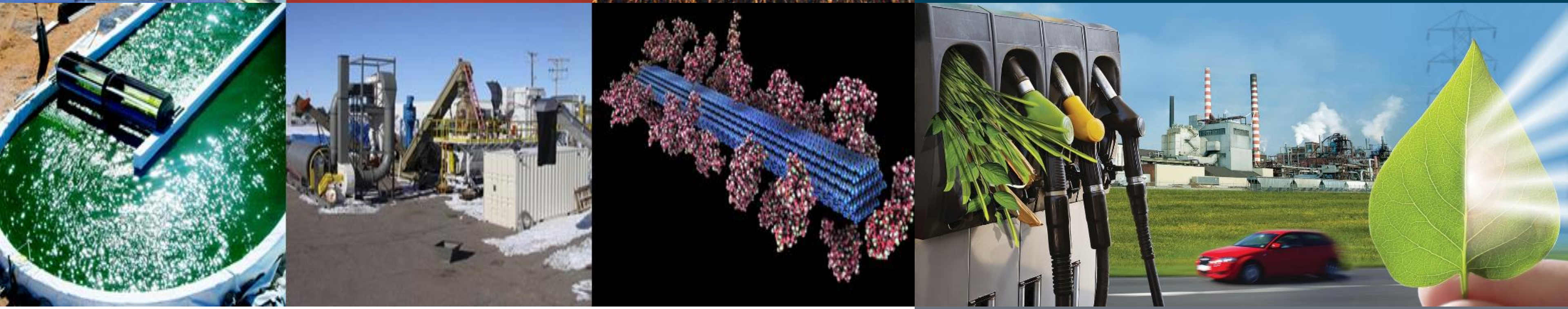

DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

Feedstock Supply Chain Analysis

WBS #:1.1.1.2

Feedstocks Platform

March 25, 2015

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

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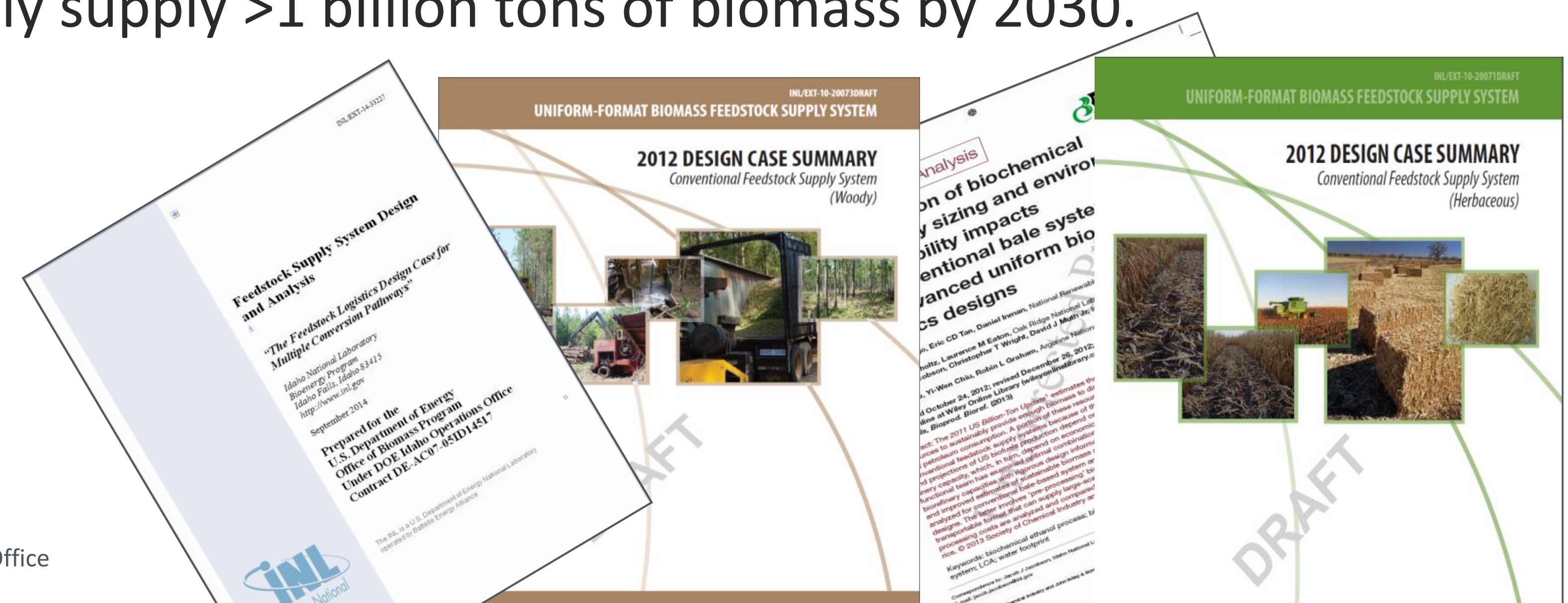
Goal Statement

Connecting the Nation's Diverse Biomass Resources to the Bioenergy Industry

The primary purpose of this project is to provide technical analysis support to the Bioenergy Technology Office (BETO) by designing advanced feedstock logistic supply systems, identifying barriers and directing research, monitoring and assessing impacts of technology improvements, supporting sustainable biofuel, and biopower development. Goal: Economically, sustainably supply >1 billion tons of biomass by 2030.



Quad Chart Overview

Timeline

- Project start date: Oct. 1, 2005
- Project end date: Sept. 30, 2017
- Percent complete: 70%

Barriers

- Barriers addressed
  - Ft-M Overall Integration
  - Ft-M Overall Quality

Budget

	Total Costs FY 10 – FY 12	FY 13 Costs	FY 14 Costs	Total Planned Funding (FY 15-Project End Date
DOE Funded (x1000)	$1,046	$712	$536	$690

Partners

- Collaborators
  - ORNL (Feedstock Supply & Sustainability)
  - NREL (Conversion & Analysis)
  - PNNL (Conversion)
  - ANL (LCA, Sustainability)
- Other Groups
  - NewBIO
  - USDA-ARS
  - Iowa State University
  - Drexel

1 - Project Overview

Programmatic Goals

- Develop cost targets and annual goals which are published in the MYPP
- Research on sustainable, high-quality feedstock supply systems
- Directs research to address barriers
- Meet conversion specifications while minimizing logistics cost
- Develop commercial-scale supply and logistics systems
- Disseminates Information to industry

Technical Goals

- Provide quantitative estimates on annual improvements progress toward 2017 cost goals (SOTs)
- Develop commercial-scale supply and logistics systems
- Disseminate practical tools that support analyses, decision making, and technology development

2 – Approach (Technical)

- Collaborate closely with the engineering and science tasks at INL, universities, industry, and other national laboratories
- Develop methodologies to support the analyses necessary to develop annual SOT's, MYPP goals, and identify barriers

- Develop and expand tools to enable advanced analysis
- Meeting DOE goals requires the integration of design improvements, achieved over years of integrated research and analysis

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2 – Approach (Management)

SUCCESS FACTORS

- Collaboration across platforms (production through conversion)
- Enhance Tools and Visualization
- Dissemination of vision and results

CHALLENGES

- Reaching key stakeholders
- Integrating data across diverse platforms

TRACKING

- Annual State of Technology Reports (9/30/15)
- Modeling a feedstock supply system that can meet the quantity target (240 million tons/yr) while hitting cost target of $80/dry ton delivered while meeting conversion quality specifications (9/30/2017)

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3 – Technical Accomplishments/ Progress/Results

Major Milestone Deliverables

- Updated Logistics cost and targets in the **2014 MYPP**
- 2014 Feedstock Logistics **Design Report** (9/30/2014)
- 2013-14 Annual State of Technology **(SOT) Reports** for both Thermochemical and Biochemical conversion pathways (12/30/2013 and 12/30/2014)
- 2014 Depot Technical Economic Assessment **(TEA) Report** (9/30/2014)
- Advanced Supply System Validation **Workshop** (2/3/2015)

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3 – Technical Accomplishments/ Progress/Results

Defined: Design Case

- Basis for setting technical targets and cost of production goals for assessing technology progress and validating processes at increasing scale and integration
- Used to prioritize R&D areas and justify budget requests
- Based on best available information and current projections of nth plant capital/operating

Defined: State of Technology (SOT)

- Periodic (usually annual) assessment of the status of technology development for a biomass to biofuels/products pathway
- Assesses progress within and across relevant technology areas based on actual experimental results relative to technical targets and cost goals from designs
- Includes technical, economic, and environmental criteria as available

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3 – Technical Accomplishments/ Progress/Results

Two Logistic Designs currently support 6 conversion pathways

CONVERSION PATHWAYS

Biochemical Logistics Design

- Biological Fermentation of Sugars
- Catalytic Upgrading of Sugars

Thermochemical Logistics Design

- Fast Pyrolysis
- In-Situ Catalytic Fast Pyrolysis
- Ex-Situ Catalytic Fast Pyrolysis
- Syngas Upgrading

Algal Lipid Upgrading

Whole Algae Hydro. Liquefaction

Component	Composition (dry wt. %)
Glucan	35.05
Xylan	19.53
Lignin	15.76
Ash	4.93
Acetate	1.81
Protein	3.10
Extractives	14.65
Arabinan	2.38
Galactan	1.43
Mannan	0.60
Sucrose	0.77
Total structural carbohydrate	*58.99*
Total structural carbohydrate + sucrose	*59.76*
Moisture (bulk wt.%)	*20.0*
Particle Size	*¼ inch*

Component	Composition (dry wt. %)
Carbon	50.94
Hydrogen	6.04
Nitrogen	0.17
Sulfur	0.03
Oxygen	41.90
Ash	0.90-1.0
Heating Value (Btu/lb)	8,601 HHV
	7,996 LHV
Moisture (Bulk Wt. %)	10.0
Particle Size (mm)	2

3 – Technical Accomplishments/ Progress/Results

Thermochemical Design

2011 Dollars	2013 SOT	2014 SOT	2015 Proje	2016 Proje	2017 Proje	2018 Proje	2019 Projecti
Feedstock Type	Pine	Pine	Blend	Blend	Blend	Blend	Blend
Total Delivered $/dry ton	$ 102.12	$ 101.45	$ 92.36	$ 86.72	$ 80.00	$ 80.00	$ 80.00
Grower Payment $/dry ton	$ 25.00	$ 25.00	24.43	$ 23.45	$ 21.90	$ 21.90	$ 21.90
Total Feedstock Logistics $/dry ton	77.12	76.45	67.93	63.27	58.10	58.10	58.10
Harvest and Collection	22.24	22.24	16.68	14.46	10.47	10.47	10.47
Landing Preprocessing	12.17	12.17	11.37	11.02	10.24	10.24	10.24
Transportation and Handling	14.84	14.84	12.47	8.48	7.52	7.52	7.52
In-Plant Receiving and Processing	27.87	27.20	27.41	29.31	29.87	29.87	29.87
Total Feedstock Logistics $/gal total fuel	0.88	0.87	0.77	0.72	0.66	0.66	0.66
Harvest and Collection	0.25	0.25	0.19	0.16	0.12	0.12	0.12
Landing Preprocessing	0.14	0.14	0.13	0.13	0.12	0.12	0.12
Transportation and Handling	0.17	0.17	0.14	0.10	0.09	0.09	0.09
In-Plant Receiving and Processing	0.32	0.31	0.31	0.33	0.34	0.34	0.34
Gallons total fuel/dry ton	88.00	88.00	88.00	88.00	88.00	88.00	88.00

Optimized for single Feedstock – Can't achieve $80/dry ton

Blends enable cost savings necessary to hit cost targets

Additional cost savings come from engineering advancements such as fractional milling, wet densification and more efficient drying techniques.

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3 – Technical Accomplishments/ Progress/Results

2015 Advanced Supply System Workshop Objectives

- Validate, modify or refute Advanced Supply System (or “depot design”) fundamental assumptions:
  - Biorefinery Scale (cost and quantity session)
  - Need for “active” preprocessing, blending, and densification (quality session)
  - Feedstock variability and uncertainty has a cost (risk and finance session)
- Discuss/explore industry scale Advanced Supply System solutions (e.g., 1 billions tons/year)
- Document expert opinion regarding transitioning from present day to tomorrow’s advanced supply systems.
- Collect & Document expert opinions that can:
  - Inform the DOE Feedstock R&D plan moving forward
  - Shape the analysis for the Billion Ton 2016 update

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3 – Technical Accomplishments/ Progress/Results

Workshop Structure

Participants

- 35 Experts from Industry, and Academia Invites
- 27 Experts attended (5 Academia, 22 Industry)
- Industry included biorefinery managers, equipment manufacturers, consultants

1.5 days total with 3 main sessions (Scaling, Quality, Risk)

Computer Moderated Sessions (Think T

Over 35 Megabytes of Data Collected

Note: They all provided their own travel expenses

3 – Technical Accomplishments/ Progress/Results

Assumptions List

Assumption: Feedstock supply systems limit biorefinery economies of scale.	
Cost and Quantity	Barriers: 1. Biorefinery scaling up will be limited under the current supply system design. 2. Infrastructure will limit scale (transportation, storage…). 3. Variable and uncertain feedstock availability will limit biorefinery size. 4. Scale will require biorefineries to use a diversity of feedstocks
Assumption: Quality is limiting to the biorefining industry and must be managed in the feedstock supply system.	
Quality Constraints	Barriers: 1. Variability exists and will be important at the scale of a single biorefinery (due to weather events, flood, drought and rain) 2. Variability increases biorefinery cost and risk 3. Quality attributes must be managed to achieve expected performance 4. Specification targets are ever moving and evolving 5. Cost to value added
Assumption: Risk is important to the biorefinery and must be managed in the feedstock supply system.	
Operational & Financial Risk	Barriers: 1. Cost 2. Transitioning from Conventional to Advanced 3. Feedstock Competition

3 – Technical Accomplishments/ Progress/Results

Workshop Consensus

Two Themes resonated from the participants:

- The Distributed Depot Design is the Future
- Transition from Current to Future is Vital

Bottom Line: Back to work designing the future

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4 – Relevance

BETO:

The biomass logistics analysis is a critical part of the overall biofuel production system. The greatest contribution to the program from this task is the thought leadership on to transform from the current thinking towards an agri-business concept.

- **2014 Design Case:** Developed a path forward to the 2017 $80/dry ton cost target.
- **SOTs:** Annually assess supply system costs associated with using current state of technology (SOT).
- **MYPP:** Develop designs and cost targets for the different conversion platforms based on projected advancements from research in feedstock logistic equipment and processes.
- **Publications**: Over a dozen peer reviewed publications/presentations in last 4 years.

Industry, Universities & Other National Labs:

- **Collaborate** with the engineering and science tasks, provide systems analysis that interface between feedstock production and conversion in-feed requirements.
- **Analytical services** on supply system logistics to other national laboratories, universities, and industry partners.

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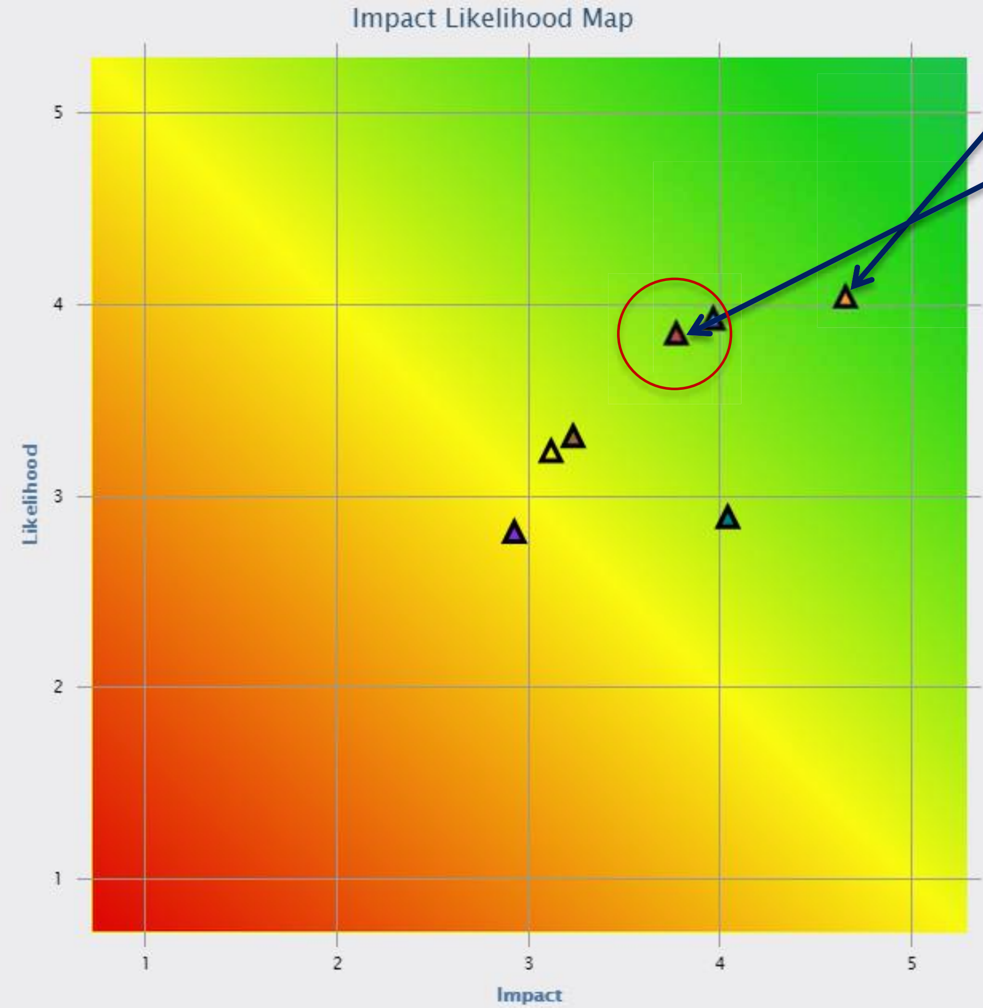
4 – Relevance

Heat Map of Solutions from Advance Supply System Validation Workshop



- Expert opinion (industry and academia) solicited
- Rank solutions by impact on Billion Ton Economy and likelihood of success
- Markets critical to industry success
- Depots a logistics solution

5 – Future Work

- Develop SOT’s to include business cases. Move beyond engineering designs only.
- Develop enhanced algorithms and tools for assessing depot sizing, location, operational strategies (multiple feedstocks, multiple pathways…)
- The culmination of this project will result in a national biomass supply system capable of delivering large quantities of biomass at the BETO target of $80/dry ton. The results of this assessment will published in a peer reviewed journal. (9/30/2017)

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Summary

- This project is where the thought leadership is developed. Understanding what are the limitations, barriers and opportunities.
- This project is the interface between the engineered processes and the decision makers.
- Being responsive to BETO and other labs is a big part of this project.
- Collaboration is key! Not only within the INL but with BETO, the other National Labs, industry and universities.
- Publishing and disseminating the information derived from this project is important.

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Questions

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Responses to Previous Reviewers' Comments

- This project provided some very relevant data collection and categorization to address feedstock characteristic issues. Analysis and analogy to feedstock blending is interesting, however its due to the low-value, high-volume nature of feedstock (versus feed) are unexplored.
  - We have expanded our research on least cost formulation to analyze the competition and value of blended feedstocks and linked the toolset to the Biomass Research Library at INL.
- There are some issues regarding data availability and appropriateness of extrapolation, but these are acknowledged with a plan in place to address analysis gaps.
  - We have expanded our datasets, linked with the KDF, Biomass R&D Library and Billion Ton Update to improve our datasets.

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Publications, Patents, Presentations, Awards, and Commercialization

- *Book Chapter: Technologies for the Production of Heat and Electricity,* Book Title: Cellulosic Energy Cropping Systems. Wiley Publications, Status: Published. Authors, Jacob Jacobson, Kara Cafferty. Jan 2014
- *Lignocellulosic feedstock supply systems with intermodal and overseas transportation*, Ric Hoefnagels, Erin Searcy, Kara Cafferty, Thijs Cornelissen, Martin Junginger, Jacob Jacobson, André Faaij. July 2014
- *Variable cost analysis for high-volume and long-haul transportation of densified biomass and biofuel*, Md. S. Roni, Sandra D. Eksioglu, Erin Searcy, Jacob J. Jacobson. May 2014
- *Investigation of Thermochemical Biorefinery Sizing and Environmental Sustainability Impacts for Conventional Supply System and Distributed Preprocessing Supply System Designs*, Muth, D.J., M. Langholtz, A. Argo, E. Tan, A. Dutta, L. Eaton, C. Brandt, J. Jacobson, E. Searcy, K. Cafferty, M. Wu, Y. Chiu. March 2014.
- *Investigation of Biochemical Biorefinery Sizing and Environmental Sustainability Impacts for Conventional Bale System and Advanced Uniform Biomass Logistics Designs*. R. Graham, M. Langholtz, L. Eaton, J. Jacobson, C. Wright, D. Muth, D. Inman, E. Tan, M. Wu, Y.-W. Chiu, S. Jones, L. Snowden-Swan, A. Argo, BioFPR, (April, 2013).
- *Biomass Depot TechnoEconomic Analysis* – September, 2014, Patrick Lamers, Jacob J. Jacobson, Md. Mohammad Roni, Kara Cafferty.
- *Biomass Feedstock Logistics Design Report Update with pathway specific analysis. September 2014*. Md. Mohammad Roni, Jacob J. Jacobson, Patrick Lamers, Kara Cafferty, Jason Hansen.

Publications, Patents, Presentations, Awards, and Commercialization

- *Feedstock Handling and Processing Effects on Biochemical Conversion to Biofuels,* Inman, D. , Nagle, N., Jacobson, J. Searcy E., Ray, A.E., Biofuels, Bioproducts and Biorefining, Volume 4, Issue 5, September 2010
- *Least Cost Formulation of Biomass to Reduce the Cost of Renewable Hydrocarbon Fuels*, Dave Muth, Robert Jeffers, Jake Jacobson, Kara Cafferty, Kenneth Bryden, Accepted to 49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit and 11th International Energy Conversion Engineering Conference. July, 2013.
- *Programmatic Requirements for Modeling and Analysis of Feedstock Logistics,* Erin Webb, Shahab Sokansanj, Sam Tagore, Jacob J. Jacobson, American Society of Agricultural and Biological Engineers, Summer Meetings, Pittsburg. June 2010.
- *Uniform-Format Feedstock Supply System Design for Woody Biomass,* Jacob J. Jacobson, Erin Searcy, 2010 AICHE Spring Meeting and 6th Global Congress on Process Safety, American Society of Chemical Engineers. March 2010.
- *Comparison of supply system costs of forest residues when comminution is performed a landing vs at biorefinery,* Jacob J. Jacobson, Erin Searcy,, Society of Industrial Microbiology Annual Conference, April 2010.