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

Harvest, Storage, Transportation, and Technoeconomic Modeling Advances in Corn Stover Supply Chains  

March 7, 2017  
Feedstock Supply and Logistics  

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This presentation does not contain any proprietary, confidential, or otherwise restricted information
North Central Sun Grant Funded Programs

• **Evaluation of In-field Corn Stover Densification and Interaction with Storage Quality, Logistics, and Production Costs**
  – Project Period: 2009 – 2011
  – Program: North Central Sun Grant
  – Partners: DuPont Cellulosic Ethanol, AGCO, John Deere, ConocoPhillips, ADM, Alliant Energy

• **Improving Biomass Feedstock Transportation Efficiency, Economics and Emissions Via Real-time Decision Support Tools and Best Management Practices**
  – Program: North Central Sun Grant
  – Funded through a DOT grant and leveraged data from the initial grant for work on this project
  – Partners: Ohio State University, DuPont Cellulosic Ethanol, Various small business biomass haulers
Goal Statement

- Quantify fundamental baseline properties of corn stover biomass during an industrial harvest period including moisture and ash content. This information is used in developing supply chain models and informing biorefinery design requirements.
- Determine the feedstock quality influencing factors associated with commercial biomass harvesting equipment and develop innovations which balance quality and cost of industrial feedstock production.
- Develop cyber-physical systems to optimize biomass feedstock logistics through real-time information analysis and direct feedback to supply chain operators.
- Generate baseline performance metrics for biomass transportation systems and reduce transportation costs through the implementation of targeted equipment and organizational innovations.
At the launch of these projects the industrial biomass supply chain industry was in search of low cost, high quality solutions.

Initial research questions focused on developing basic information around feedstock quality, storage dynamics, and supply chain cost.

Research teams also had to develop measurement standards that are still used widely within the industrial biomass supply chain today.
Project Overview
Where We Ended

• Throughout this project the results were broadly disseminated to project collaborators who integrated research outcomes into their supply chain solutions.

• These projects led directly to a 40% reduction in overall corn stover feedstock cost and a 30% reduction in ash content.

• Project outcomes directly supported the launch of DuPont’s $300M cellulosic biorefinery in Nevada, IA as well as supporting many other feedstock development projects nationally.
Project Management Approach

• Iowa State University was responsible for all scientific planning and reporting, but many industry partners played an active roll in data collection, analysis, and program guidance.

• These projects were a true example of ideal public-private partnerships that enhanced the scientific knowledge in biomass supply chains while also directly supporting the rapid scale-up of the biorefining industry.

• Integrated teams of university and industry partners met weekly during the in-season (Aug – Dec) and bi-monthly during the rest of the year to maintain clear communication channels.
Technical Approaches for Harvest, Storage, and Transportation Innovations
Key Challenges:
These projects were the first of their kind in analyzing feedstock supply chains at an industrial scale. In many cases, standard methods for evaluation were not available which resulted in the research team overcoming both methodology and technical research challenges simultaneously.

Initially, these projects grossly underestimated the challenges associated with feedstock quality. Initial results highlights the large influence of scale on feedstock quality, particularly ash content. While solving this resulted in a success story for the project, the lack of background scientific information in this area was an early challenge.
Key Drivers of Success:

Large scale testing allowed the research team to truly understand variability and corner conditions. In total research data was collected on 100,000+ acres of corn stover production. This led to innovations to reduce risk in the supply chain.

Integrated team with expertise in analytical, biological, and mechanical systems accelerated knowledge development.

Direct partnership with industry allowed the research team to simultaneously address core foundational science issues associated with feedstock supply chains while also addressing scalability issues for commercial solutions. These projects provide an example of how future biomass feedstock programs can rapidly translate research innovations into commercial reality.
Technical Accomplishment: Supply Chain Modeling

- Achieved Supply Chain Costs ($/std. Mg)
- Achieved Cost Savings ($/std. Mg)

Baseline Cost: $95

Producers’ Participation: $90

Harvest Rate: $85

Dry Matter Loss (DML): $80

Bale Density: $75

Bale Length: $70

Bale Height: $65

Windrower Field Efficiency: $60

Windrower Transport Efficiency: $55

Baler Field Efficiency: $50

Baler Transport Efficiency: $45

Stacker Transport Efficiency: $40

Harvest Days: $35

Windrower Working Hours: $30

Baler Working Hours: $25

Final Cost: $20

Excluding Nutrients: ~$91/std. Mg

Strategy 1: Reducing Stover Collection Area, Cost Savings: ~$11/std. Mg


Strategy 3: Reducing Quantities of In-Field Machineries, Cost Savings: ~$11.5/std. Mg

- Final Cost: ~$52/std. Mg
- Total Cost Savings: ~$39/std. Mg
- Cost Reduced by ~43%
Technical Accomplishment: Biomass Densification

• This research program contributed to a 24% increase in industrial biomass densification. This includes a 9% increase from improvements in machine designs and a 15% increase from operational improvements.

• This density increase resulted in an $8/ton reduction in biomass feedstock cost caused by efficiency gains in transportation, storage, and handling of biomass bales.
Technical Accomplishment: Biomass Storage

• This project characterized the storage dynamics (water migration, temperature, and feedstock degradation) of four different storage solutions.

• The moisture migration and temperature dynamic models produced by this project are being actively used by the biomass supply chain industry to drive storage decisions.

• Results have generated industry accepted go/no-go decisions for moisture management in corn stover.

• Improved methods for measuring dry matter loss in storage have enhanced cost prediction models.
Technical Accomplishment: Biomass Transportation

- Transportation research program resulted in a 25% reduction in overall transportation costs of biomass feedstocks.

- Best management outcomes balanced both the economic efficiency goals as well as employee safety priorities which are critical to a high throughput transportation system.

- A real-time telematics solution was developed and deployed to assist with truck routing and transportation efficiency, leveraging cyber-physical systems to aid in dynamic decision support.
Technical Accomplishment: Supply Chain Management

- Cyber-physical systems were developed to provide real-time feedback supply chain operations.
- Using live data as a feedback tool to operators resulted in a 76% increase in daily productivity.
- Mobile app and web reporting resulted in 50% increase in biomass daily production per baler which substantially reduces supply chain capital expenditures.
- Key results of this work highlight the social aspect of supply chain optimization. Feedstocks are not a factory environment and the operator of the machinery plays a substantial role in defining the quality and cost metrics of the supply chain.
Technical Accomplishment: Biomass Workforce Development

- Results of this research program have had a tangible impact on workforce development in the growing biomass supply chain industry.
- Dozens of extension publications as well as in-person trainings are conducted to translate knowledge to those individuals who are executing the supply chain.
- In many ways, the translation of this work to supply chain operators has a greater and more immediate impact than the scientific publications due to the immediate need to educate operations on best management practices for high quality and low cost feedstocks.
Program Relevance

- Technological breakthroughs to improve feedstock quality through reduced ash content of the harvested biomass and maintaining quality during storage.
- Direct reduction of feedstock costs by over 40% in emerging industrial corn stover supply chains through scientific discovery and tech transfer.
- Significant achievements in workforce development to transfer scientific knowledge to supply chain operators. This directly enhances the quality, sustainability, and economic viability of feedstock supply chains.
A public-private partnership was formed to aid in rapid development of the industry through scientific research at a commercial scale. This model has been replicated throughout the agribusiness industry since for further product developments.

Several key accomplishments included new quality controls, enhanced supply chain management, and improved quality of biomass material to the biorefinery.

Economic return of the funds awarded to projects has yielded a 5x return of funds invested that has come from cost savings directly to the industry, local economic stimulus, or investment in new technologies.
Questions?
Additional Slides
Publications, Presentation, and Technology Transfer

• Publications:
  – 11 Peer Reviewed Journal Articles
  – 12 Extension Factsheets

• Presentations:
  – 100+ Extension, Outreach, and Scientific Meeting Presentations

• Technology Transfer:
  – Dozens of best practices developed through these research programs have been accepted as best practices for the Midwest industrial corn stover supply chain.