

**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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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
 - Project Period: 2015 – 2016
 - 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.

Project Overview

Where We Started



- 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



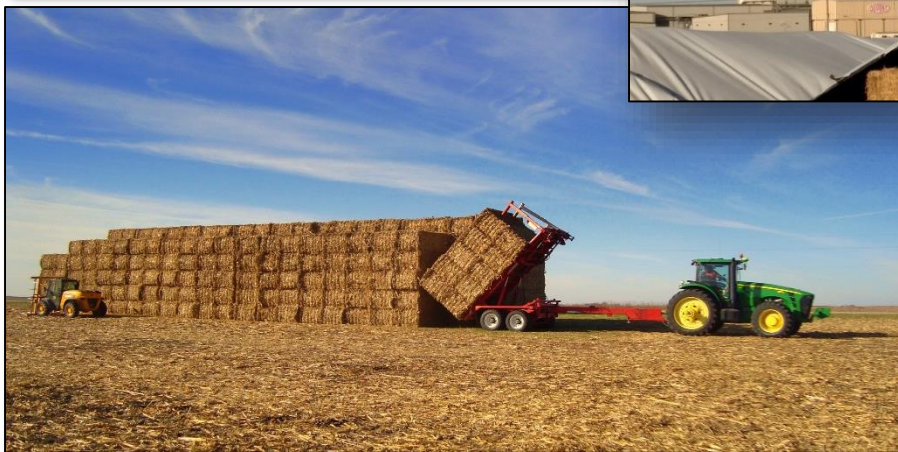
- Iowa State University was responsible for all scientific planning and reporting, but many industry partners played an active roll in data collection, analysis, and program guidance.
- These projects were a true example of ideal public-private partnerships that enhanced the scientific knowledge in biomass 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



Technical Approach for Harvest, Storage, and Transportation Innovations



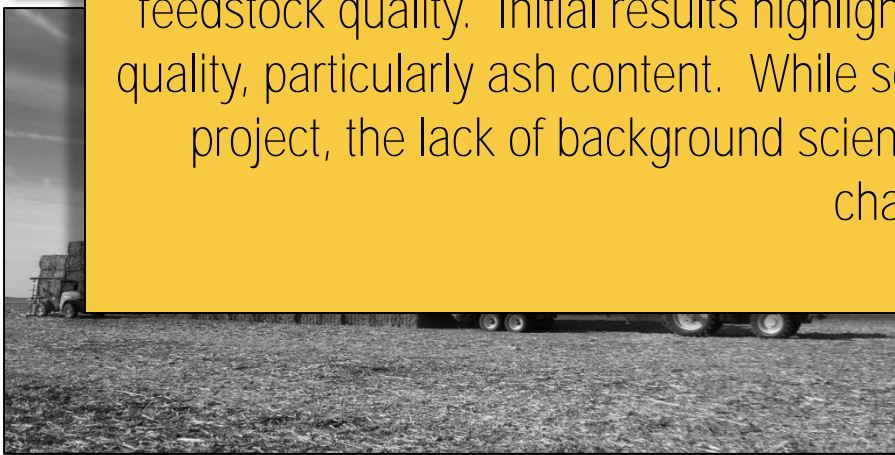
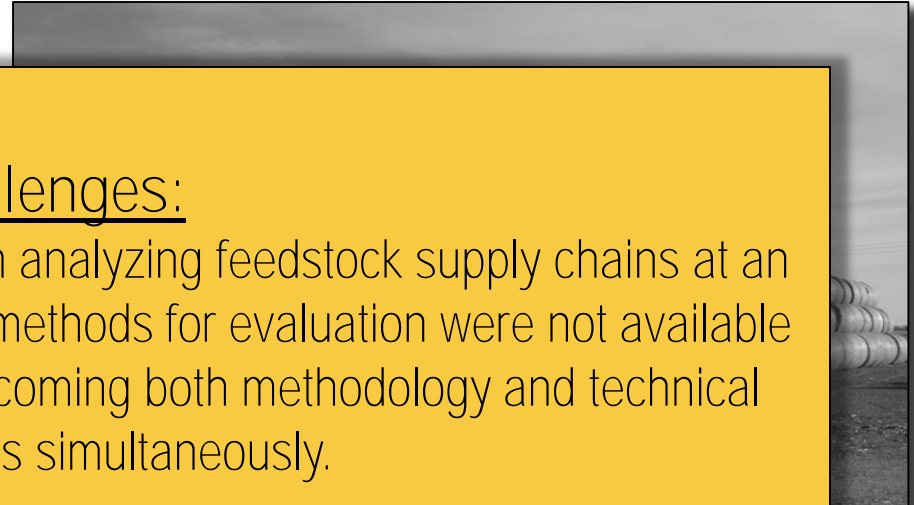
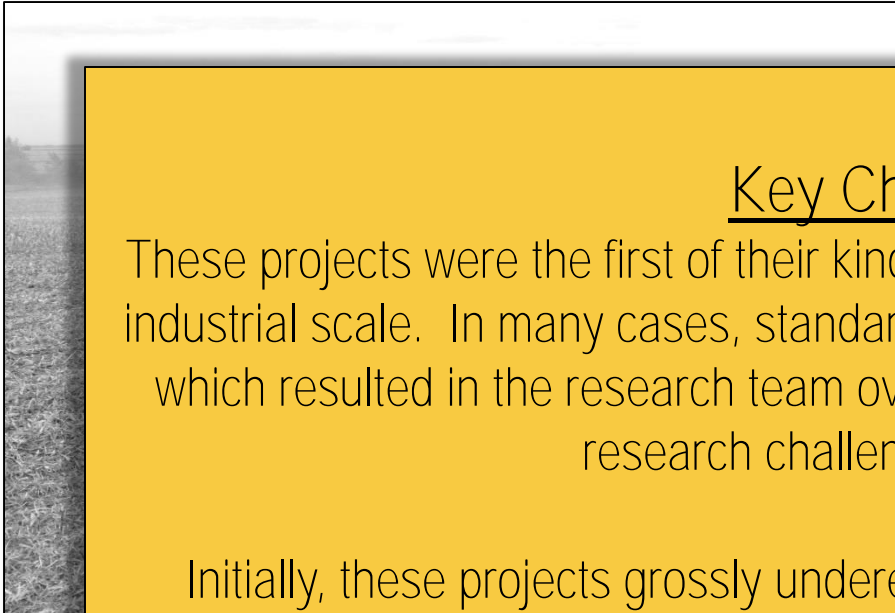
Technical Approach for Harvest, Storage, and Transportation Innovations



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.



Technical Approach for Harvest, Storage, and Transportation Innovations

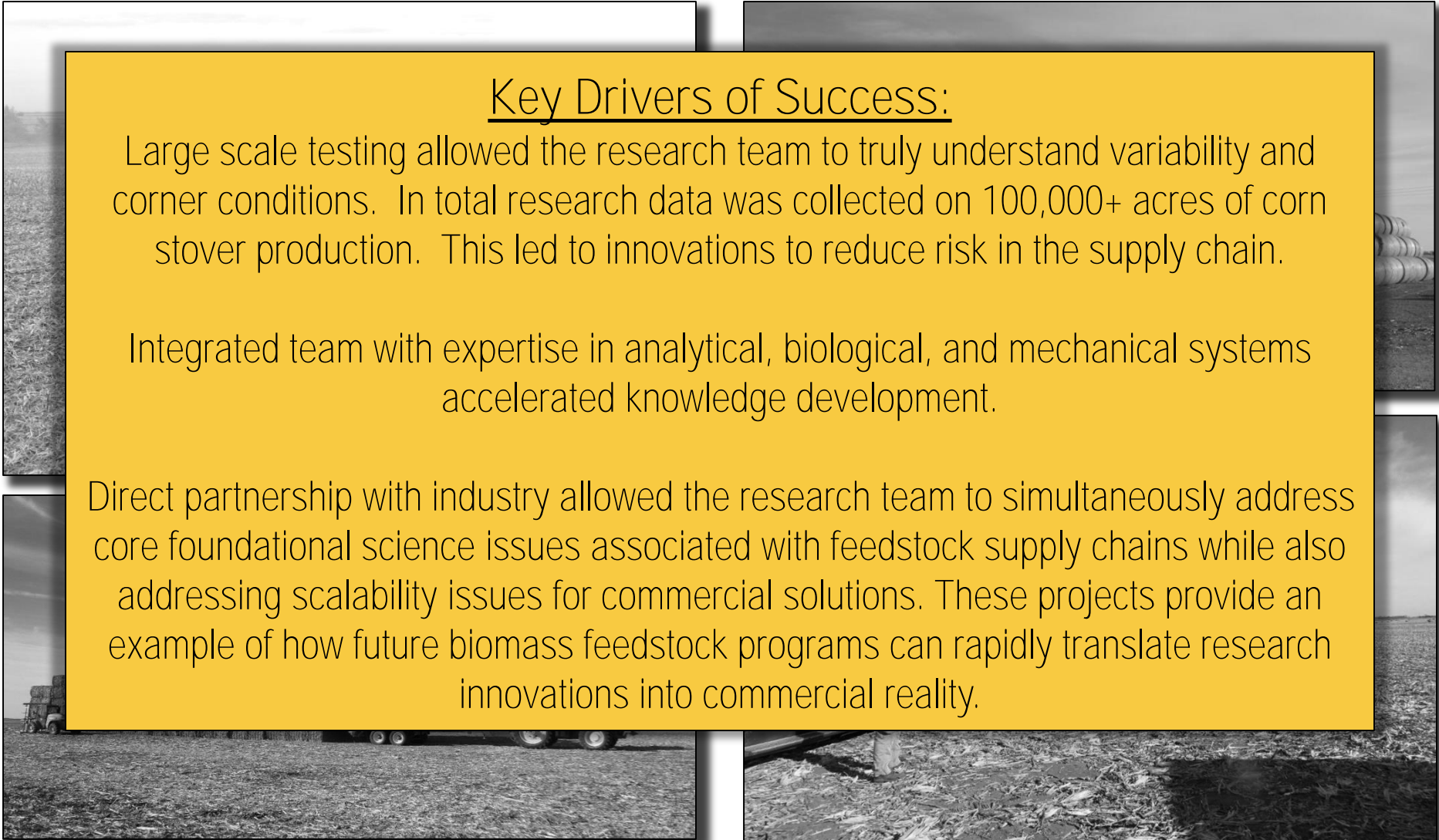


Key Drivers of Success:

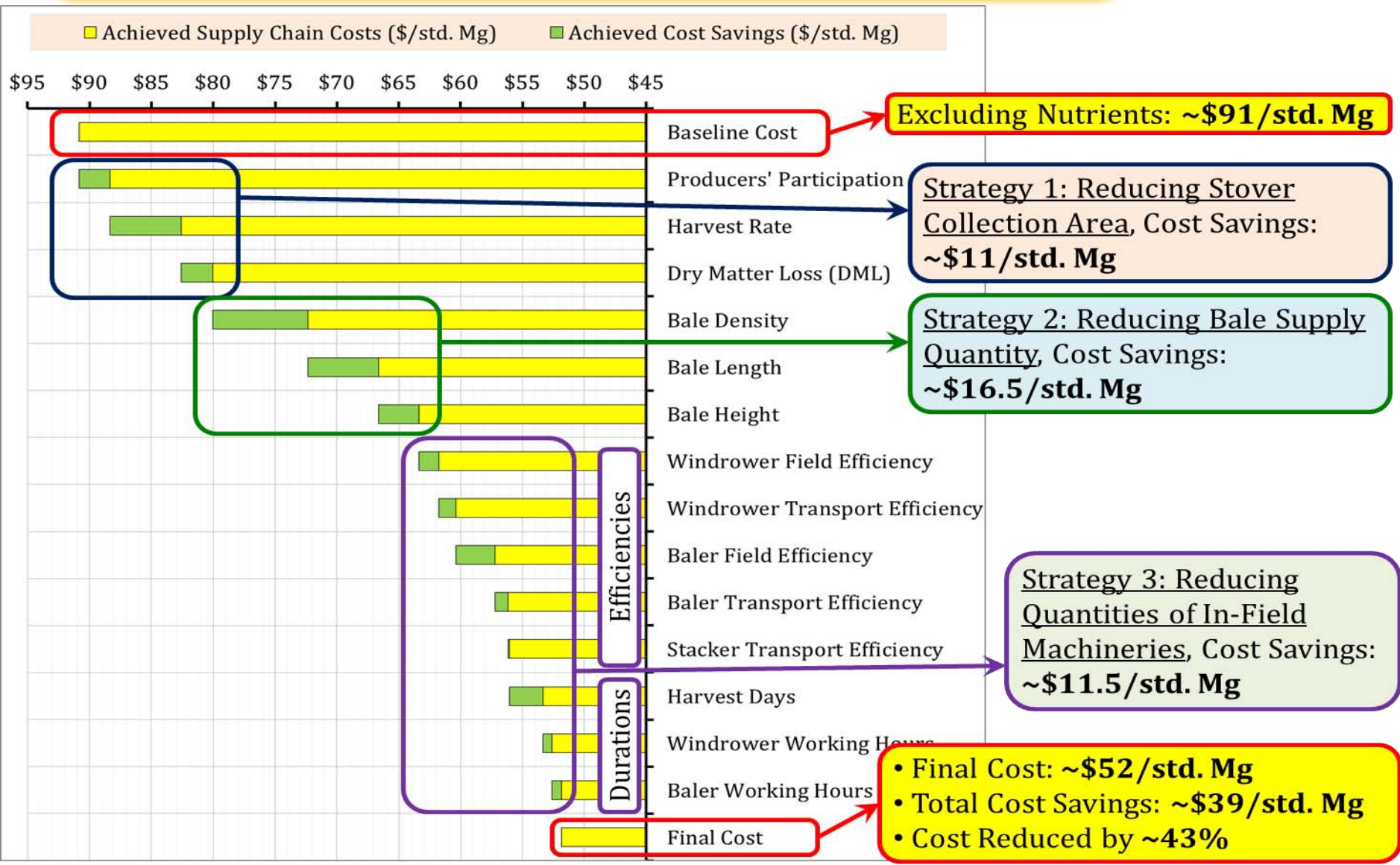
Large scale testing allowed the research team to truly understand variability and corner conditions. In total research data was collected on 100,000+ acres of corn stover production. This led to innovations to reduce risk in the supply chain.

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.



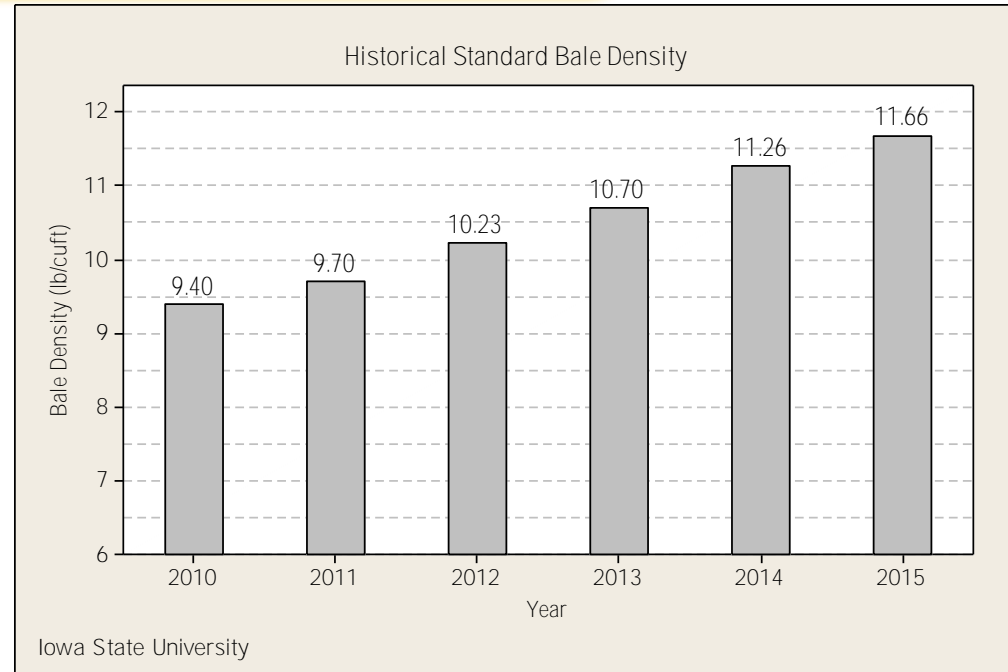
Technical Accomplishment: Supply Chain Modeling



Technical Accomplishment: Biomass Densification



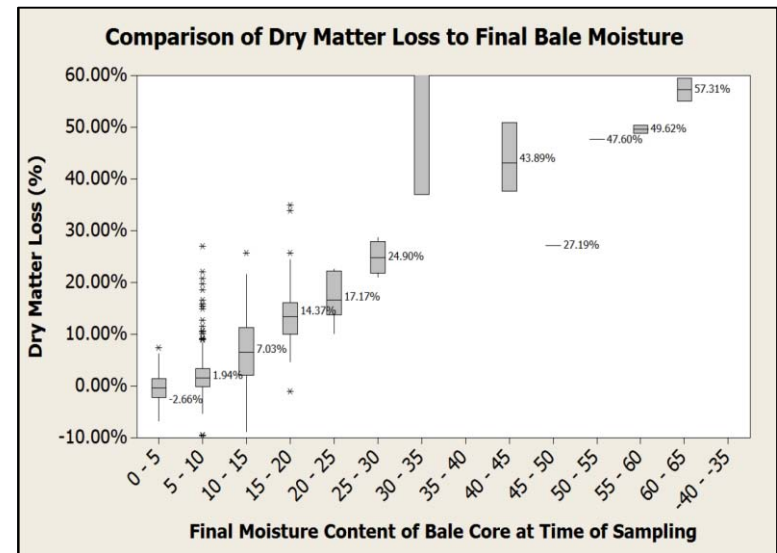
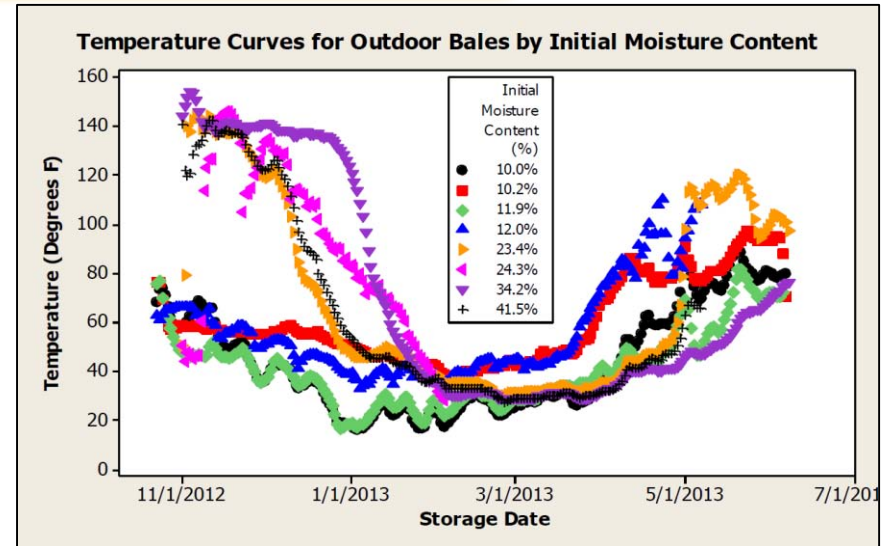
- This research program contributed to a 24% increase in industrial biomass densification. This includes a 9% increase from improvements in machine designs and a 15% increase from operational improvements.
- This density increase resulted in an \$8/ton reduction in biomass feedstock cost caused by efficiency gains in transportation, storage, and handling of biomass bales.



Technical Accomplishment: Biomass Storage



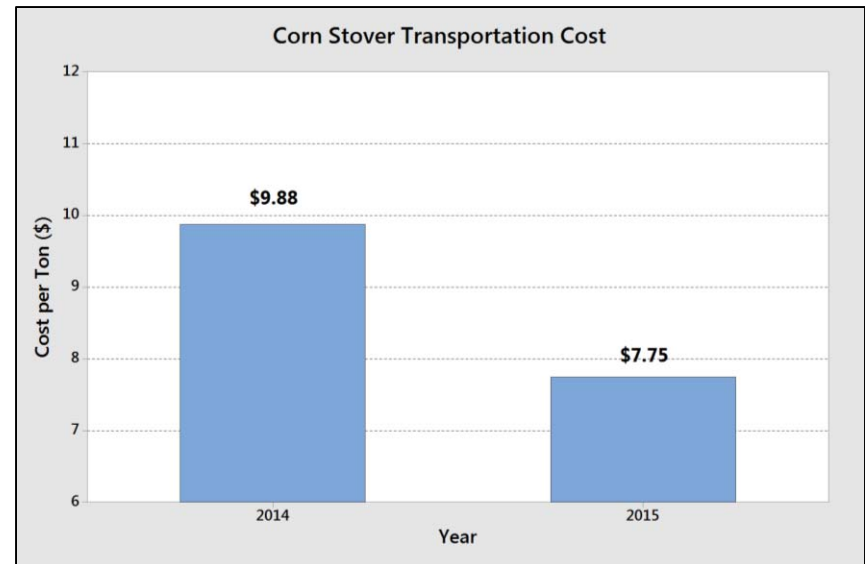
- This project characterized the storage dynamics (water migration, temperature, and feedstock degradation) of four different storage solutions.
- The moisture migration and temperature dynamic models produced by this project are being actively used by the biomass supply chain industry to drive storage 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



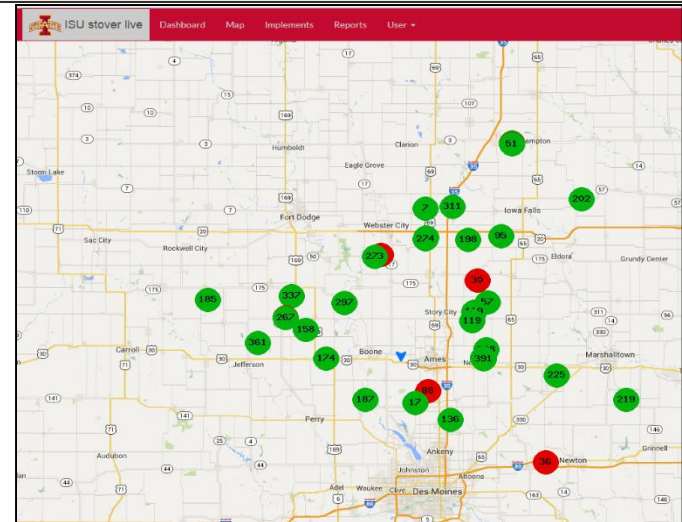
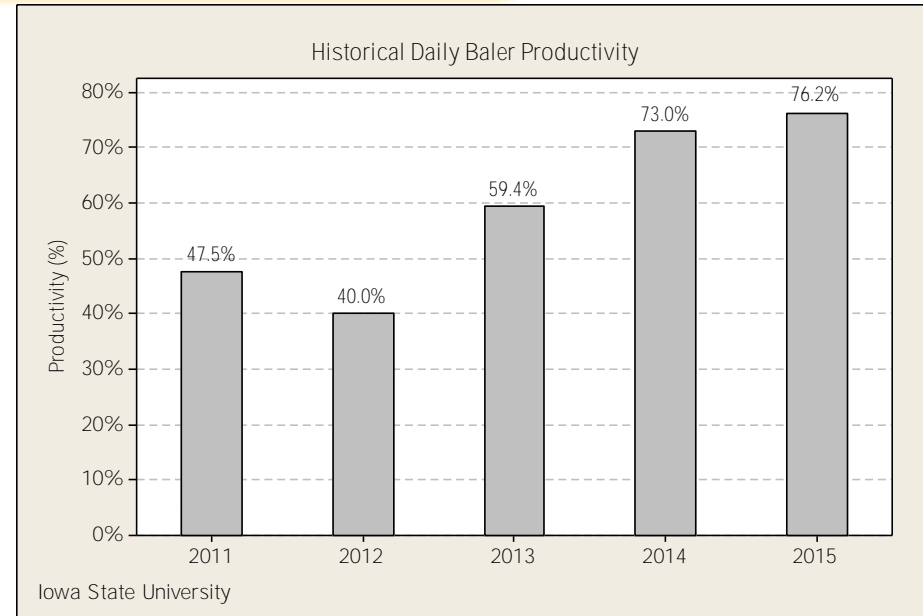
- Transportation research program resulted in a 25% reduction in overall transportation costs of biomass feedstocks.
- Best management outcomes balanced both the economic efficiency goals as well as employee safety priorities which are critical to a high throughput transportation system.
- A real-time 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



**CORN STOVER
HARVEST**



IOWA STATE UNIVERSITY
Extension and Outreach

Transporting Biomass on Iowa Roadways

Introduction

As cellulosic ethanol establishes itself as a new agricultural industry in Iowa, several thousand tons per year of biomass will need to be transported efficiently, economically, and safely from fields to storage sites and biorefineries. Commercial biomass refineries being constructed in Iowa are designed for approximately 400,000 dry tons of biomass each year. This equates to over 20,000 semi-loads of biomass bales per year or nearly 60 loads per day to the biofuels plant.

There are a number of laws governing the commercial hauling of biomass. This report provides a brief summary of driver licensing requirements, hauling configurations, load dimension restrictions, and weight restrictions that will be encountered on Iowa's roadways while transporting large square bales of biomass. All data and analysis in this report are based on standard 3 ft by 4 ft by 8 ft bales.

Transportation Methods

Midwest roadways have four main vehicle platforms used to transport square bales of biomass. They are:

1. Pick-up style light truck and trailer combination, either a goose-neck or a bumper-hitch style trailer
2. Straight truck
3. Truck tractor/semi-trailer combination, most often flatbed trailers
4. Implements of husbandry, a combination of agricultural tractor and wagons

Table 1 outlines the dimension restrictions for hauling loads on Iowa roadways. Note that these dimensions are the standard legal maximums for both primary and secondary road systems. The Iowa DOT will, for the purchase price of \$25, grant an annual permit allowing for loads of greater dimensions. It must be noted that this permit is good on only state highways and interstates. If the hauler will travel on secondary roads with oversized loads, separate county permits will be required in most cases.

Table 1. Vehicle dimension restrictions on Iowa roadways with and without oversized load permitting.

	Vehicle Length Restriction	Load Width Restriction	Load Height Restriction	Approx. Number of Bales Hauled
Pick-up Truck/Trailer	53' Trailer	8'6"	13' 6"	Depends on size of trailer (20-33)
Pick-up Truck/Trailer (With annual wide load permit)*	75' Trailer	12'5"	13' 10"	Depends on size of trailer (33-50)
Straight Truck	41'	8'6"	13' 6"	21-25
Straight Truck (With annual wide load permit)*	41'	12'5"	13' 10"	21-25
Truck Tractor/ Semi-Trailer	53' Trailer	8'6"	13' 6"	Typically 36 bales to a load
Truck Tractor/ Semi-Trailer (With annual wide load permit)*	75' Trailer	12'5"	13' 10"	Maximum is approx. 81 bales (more than likely not allowable due to weight)
Implements of Husbandry	No Restriction	No Restrictions	13'10"	One tractor may pull up to three trailers

Weight Restrictions

Transportation of biomass must meet state guidelines for vehicle weight as well. The restriction most commonly used is Gross Vehicle Weight (GVW) and primary highways (i.e., state highways, federal highways, and interstate highways) have a gross vehicle weight limit of 80,000 lbs. For the purposes of this report, the assumption is that the average truck tractor or flatbed combination will weigh approximately 30,000 lbs.

Based on an average bale dry weight of 950 lbs, a 48-ft trailer hauling 36 bales will only become weight-limited if the moisture content of the bales is above 30 percent

- 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.



Summary



- 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.