Optimization of Biomass Harvesting and Supply Chain Logistics

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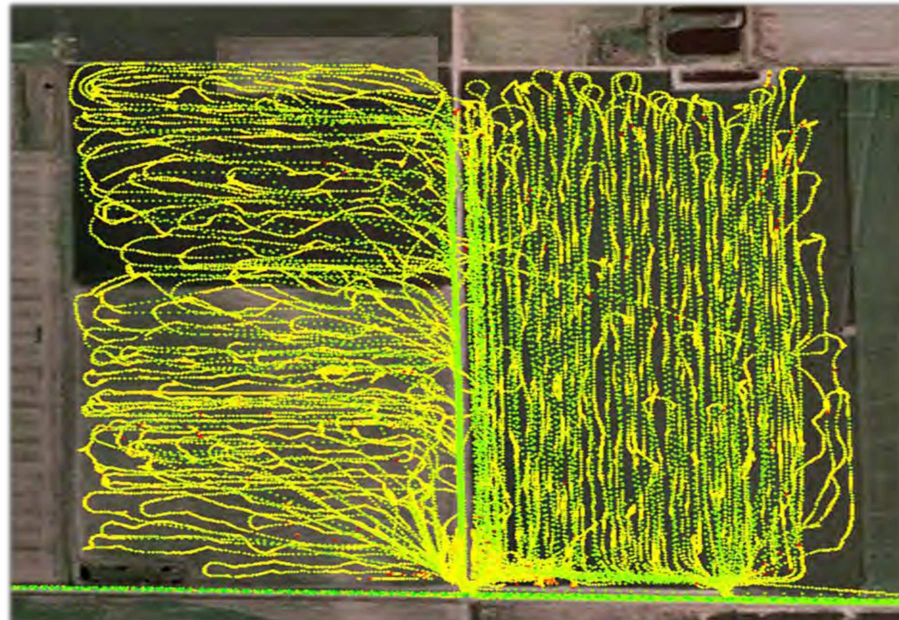
Iowa State Biomass Feedstock Supply Experience

- Research partner for corn stover harvest on nearly 15,000 acres over the past 4 years.
- Combined expertise in harvest, storage, and transportation as well as geographic supply modeling and variable rate harvesting.
- Co-located with biochemical and thermochemical conversion researchers.



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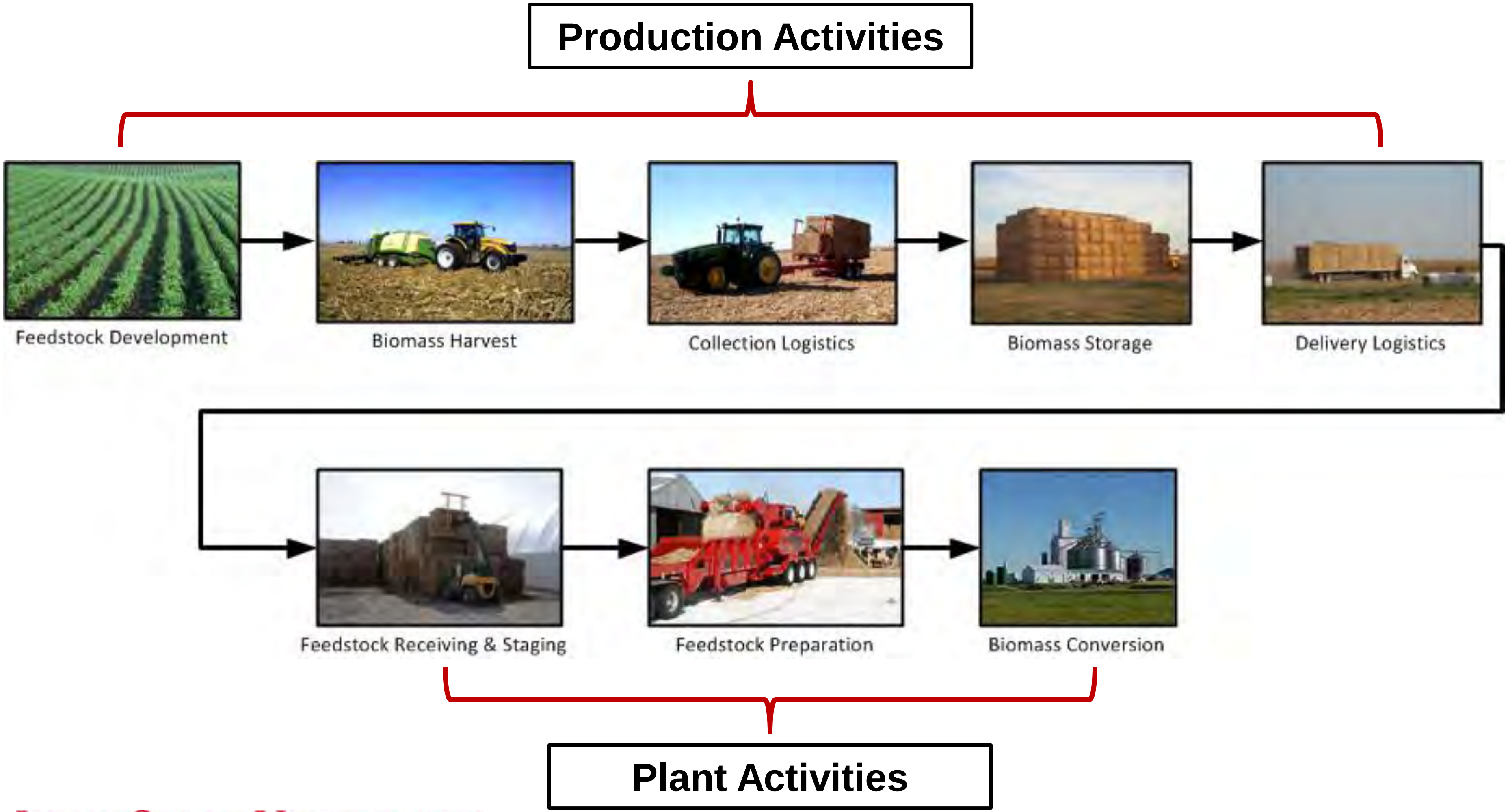
Biorefineries in the News

- Nevada, IA – DuPont Cellulosic Ethanol Plant, 28M gallons/year
- Emmetsburg, IA – POET Cellulosic Ethanol Plant, 25M gallons/year
- 25M gallons/year cellulosic ethanol plant will require 335,000 tons of biomass per year.
  - Approximately ***670,000 large bales*** of corn stover per year.
- Biorefineries desire uniform feedstock with "low" ash content and "low" moisture content.

Corn Stover Supply Chain



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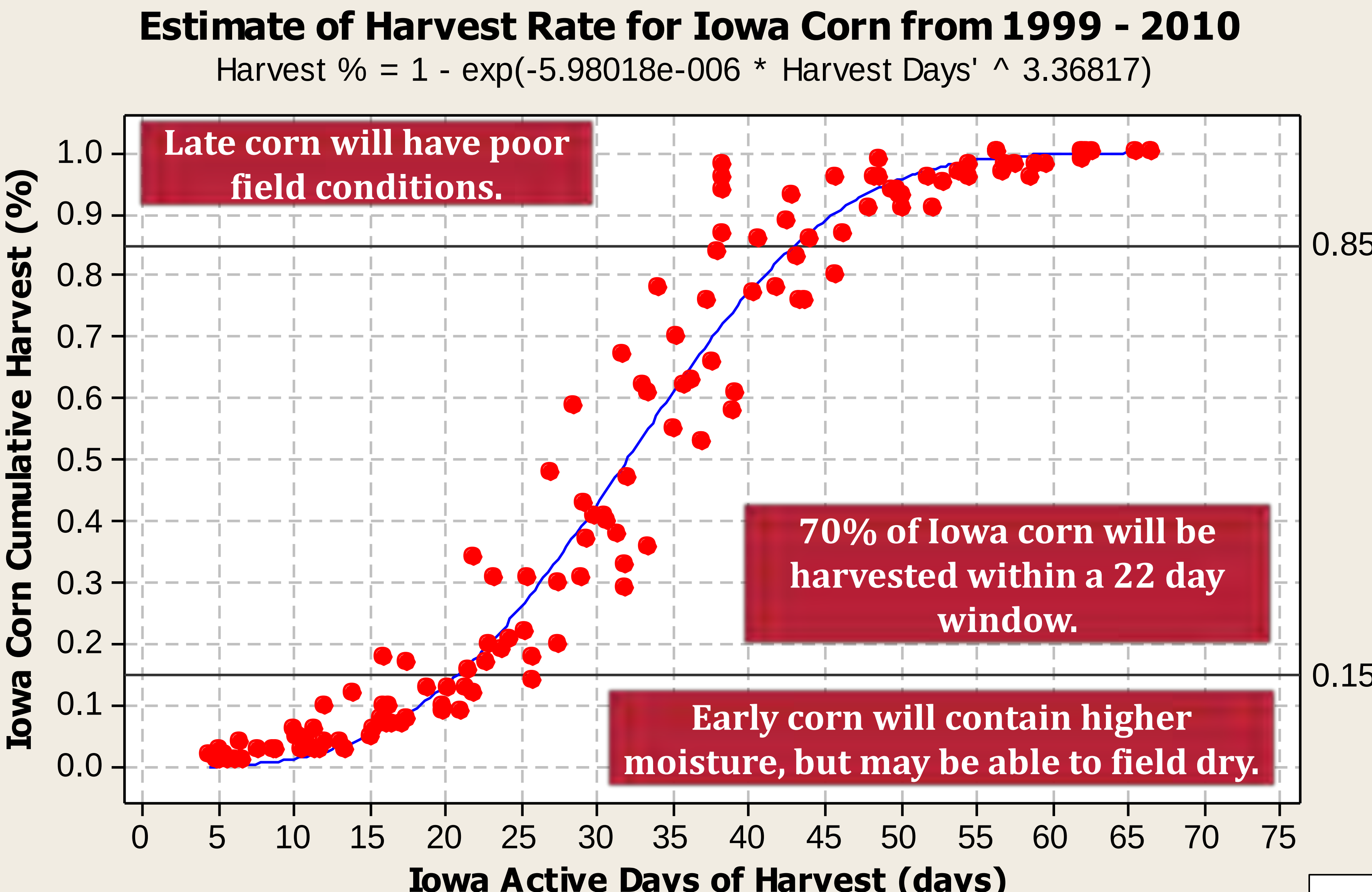
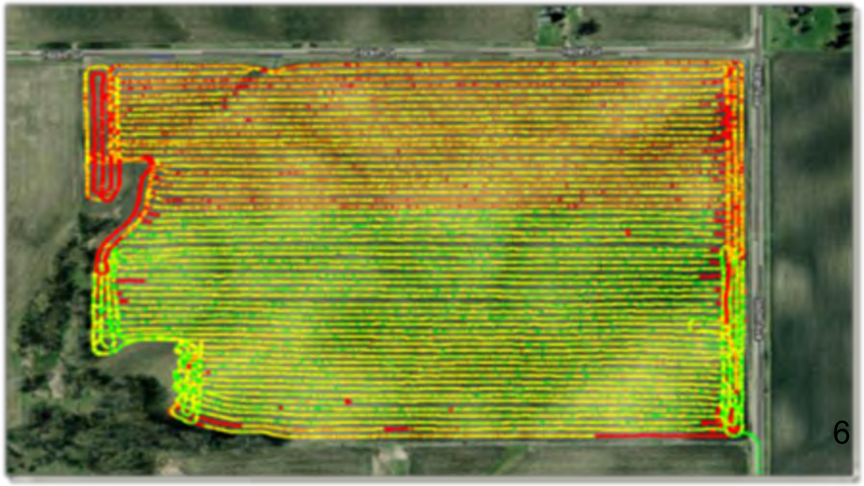
Iowa Harvest Rate from 1999 - 2010



Machinery Logistics Analysis




DEERE
644K
394 ARU
Stinger
Stinger

Corn Stover Supply Chain Costs

$16/ton	$23/ton	$8/ton	$8/ton	$15/ton

Current best case delivered cost of ag residue feedstock is $70/ton in a vertically integrated supply chain.

Engineering Tools for Supply Chain Optimization

Data Collection

Analysis

- Time in motion studies of machinery performance.
- Discrete event modeling of complete harvest, storage, and transportation system.
- Monte Carlo simulation and sensitivity modeling.

- Results provide direction for key metrics and performance indicators which are critical for supply chain optimization.

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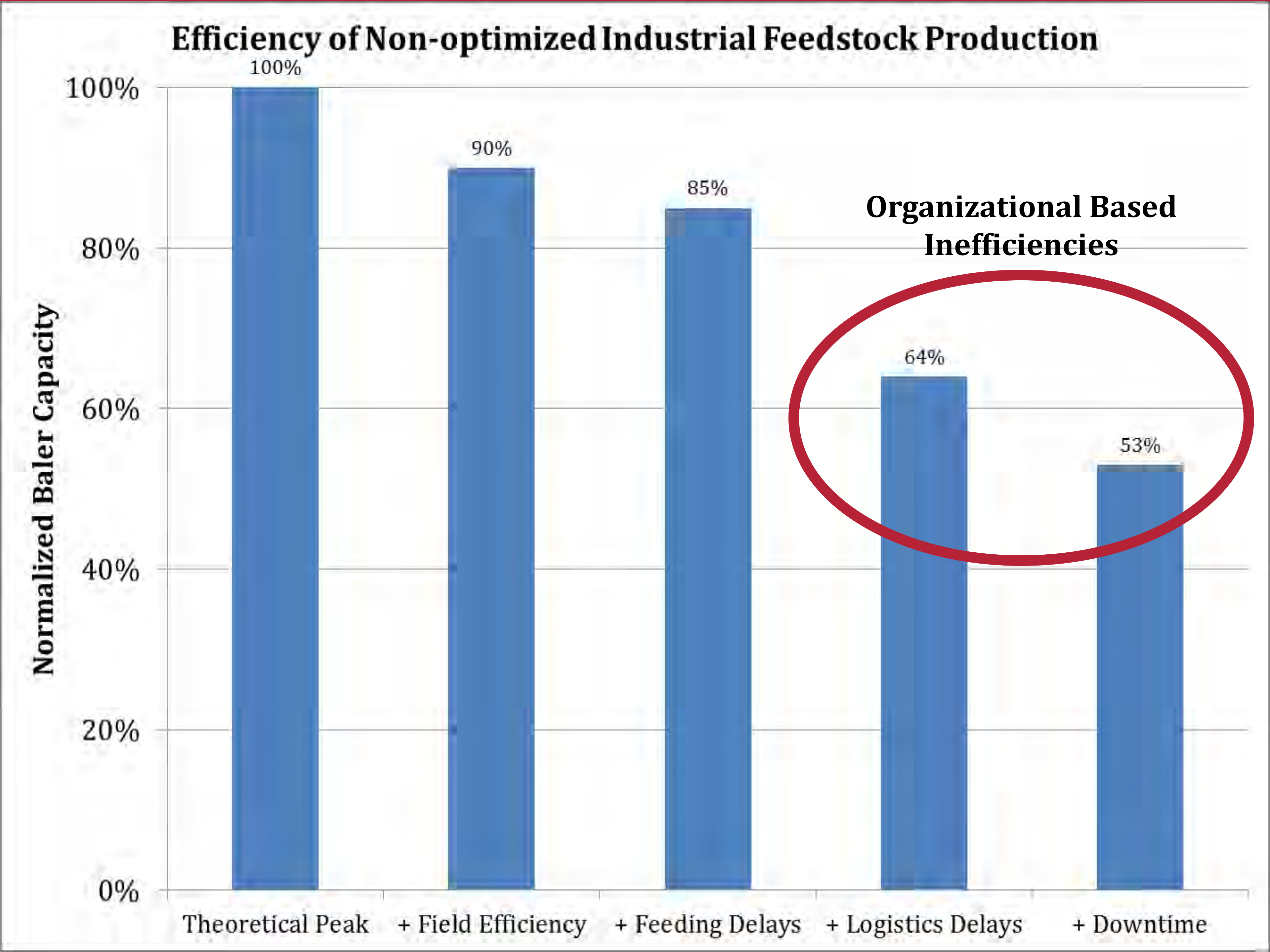
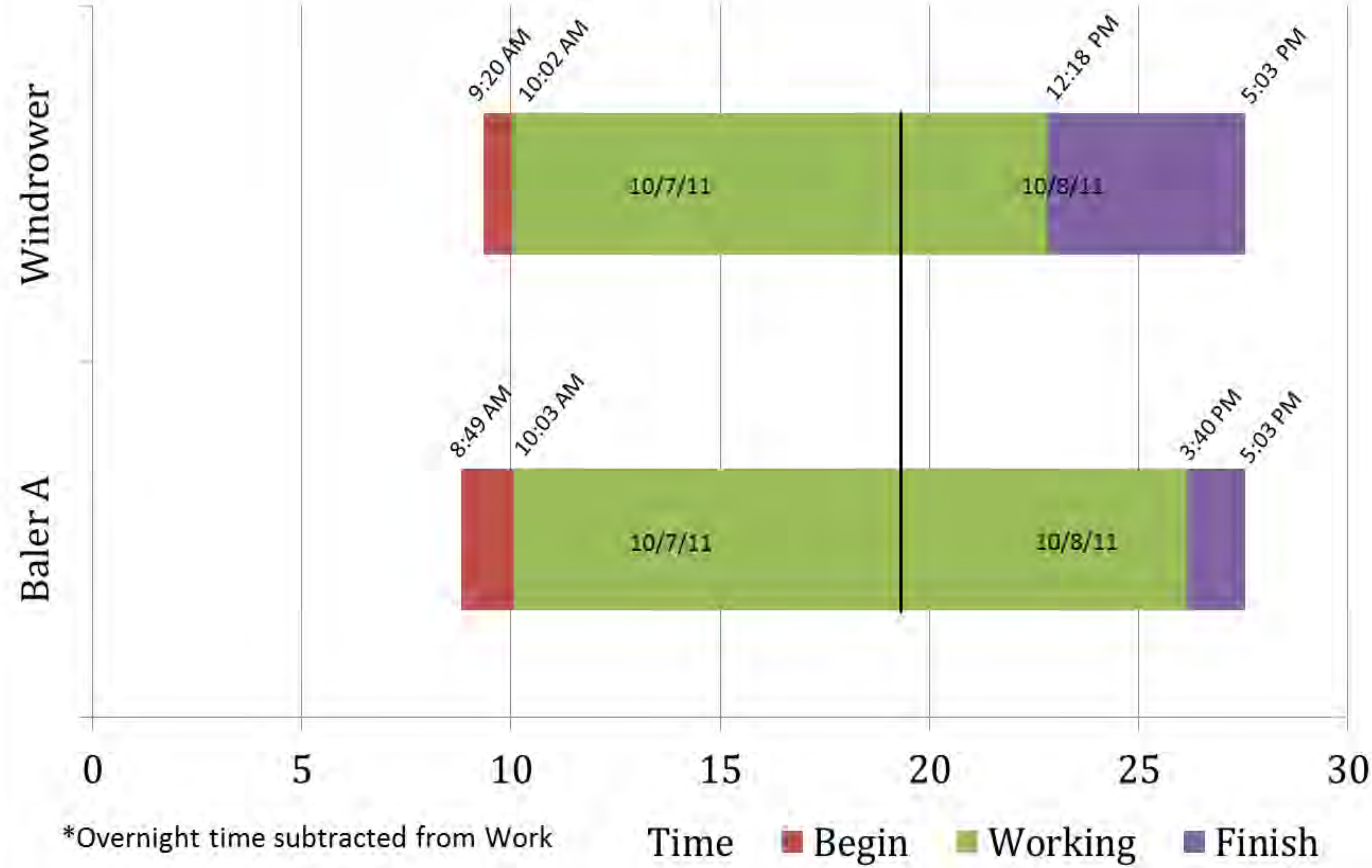
Feedstock Cost Drivers

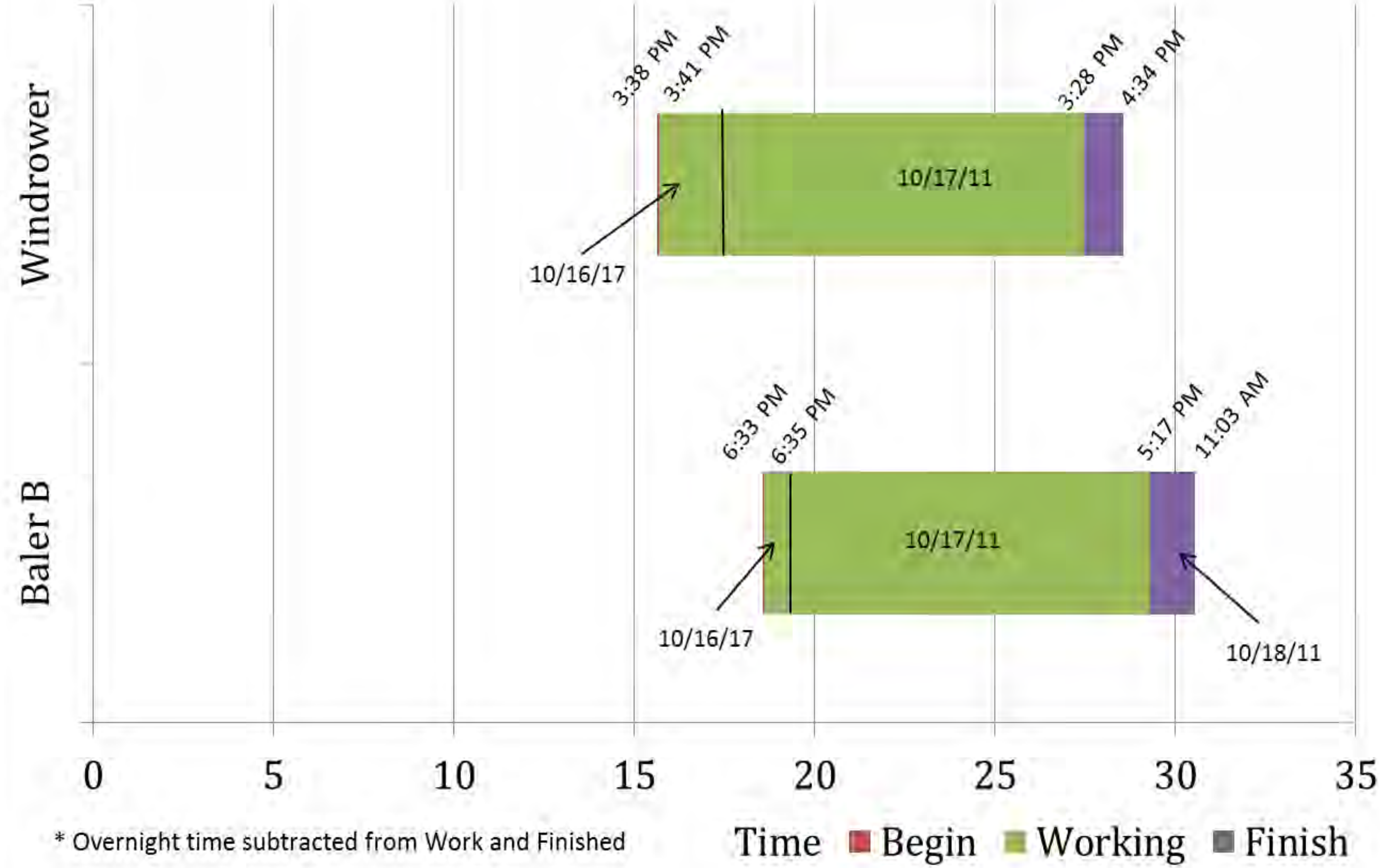
- Key Factors:
  - Bale density
  - Baler productivity
  - Nutrient replacement and feedstock production
  - Transportation efficiency
- Cost Goals:
  - Biorefinery: Minimum
  - Producer: Maximum

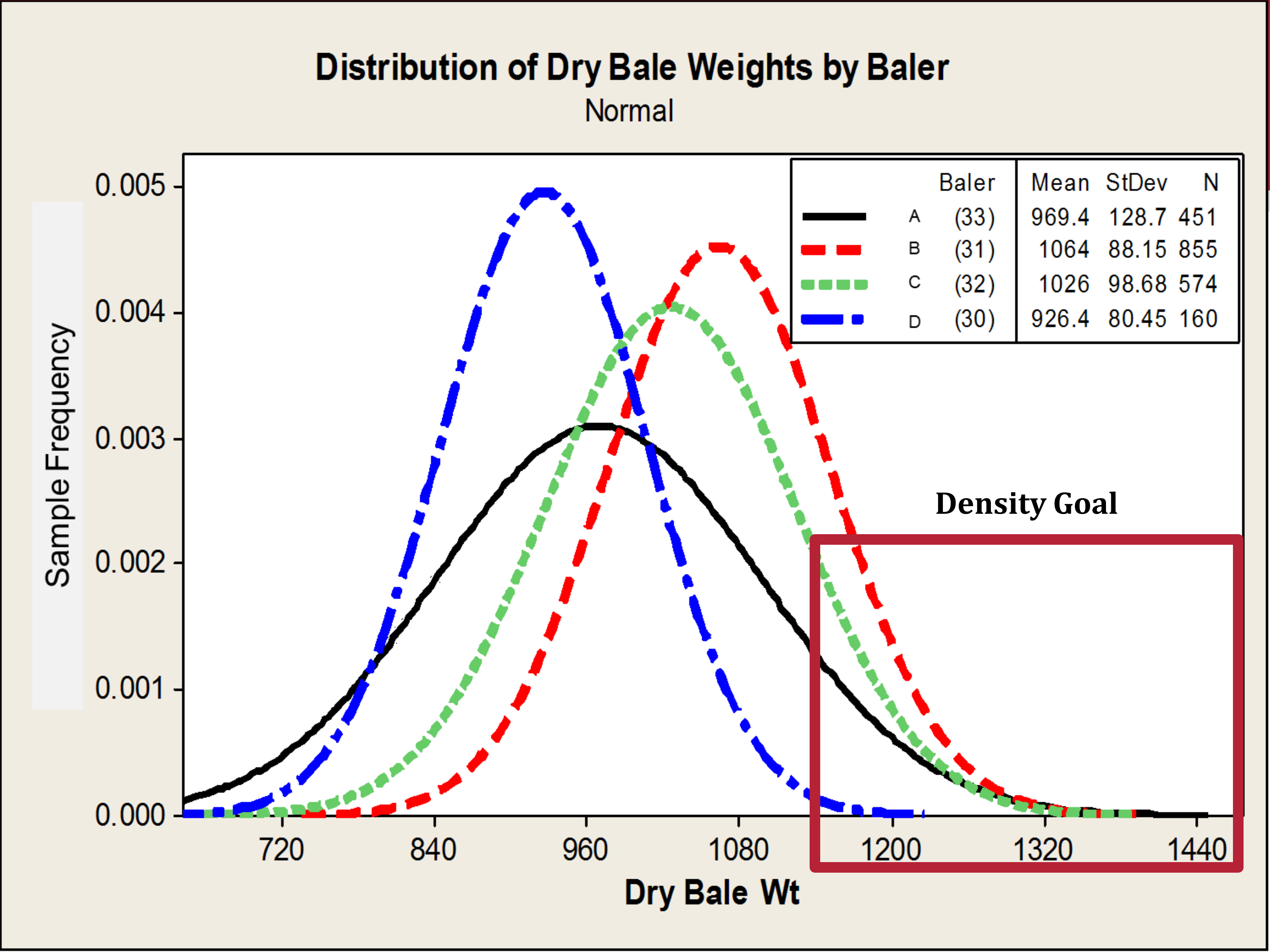

Efficiency of Non-optimized Industrial Feedstock Production
Normalized Baler Capacity
100%
80%
60%
40%
20%
0%
100%
90%
85%
64%
53%
Organizational Based Inefficiencies
Theoretical Peak
+ Field Efficiency
+ Feeding Delays
+ Logistics Delays
+ Downtime

Organizational Logistics



Organizational Logistics





Distribution of Dry Bale Weights by Baler
Normal
Sample Frequency
0.005
0.004
0.003
0.002
0.001
0.000
720
840
960
1080
1200
1320
1440
Dry Bale Wt
Baler
Mean StDev N
A (33) 969.4 128.7 451
B (31) 1064 88.15 855
C (32) 1026 98.68 574
D (30) 926.4 80.45 160
Density Goal

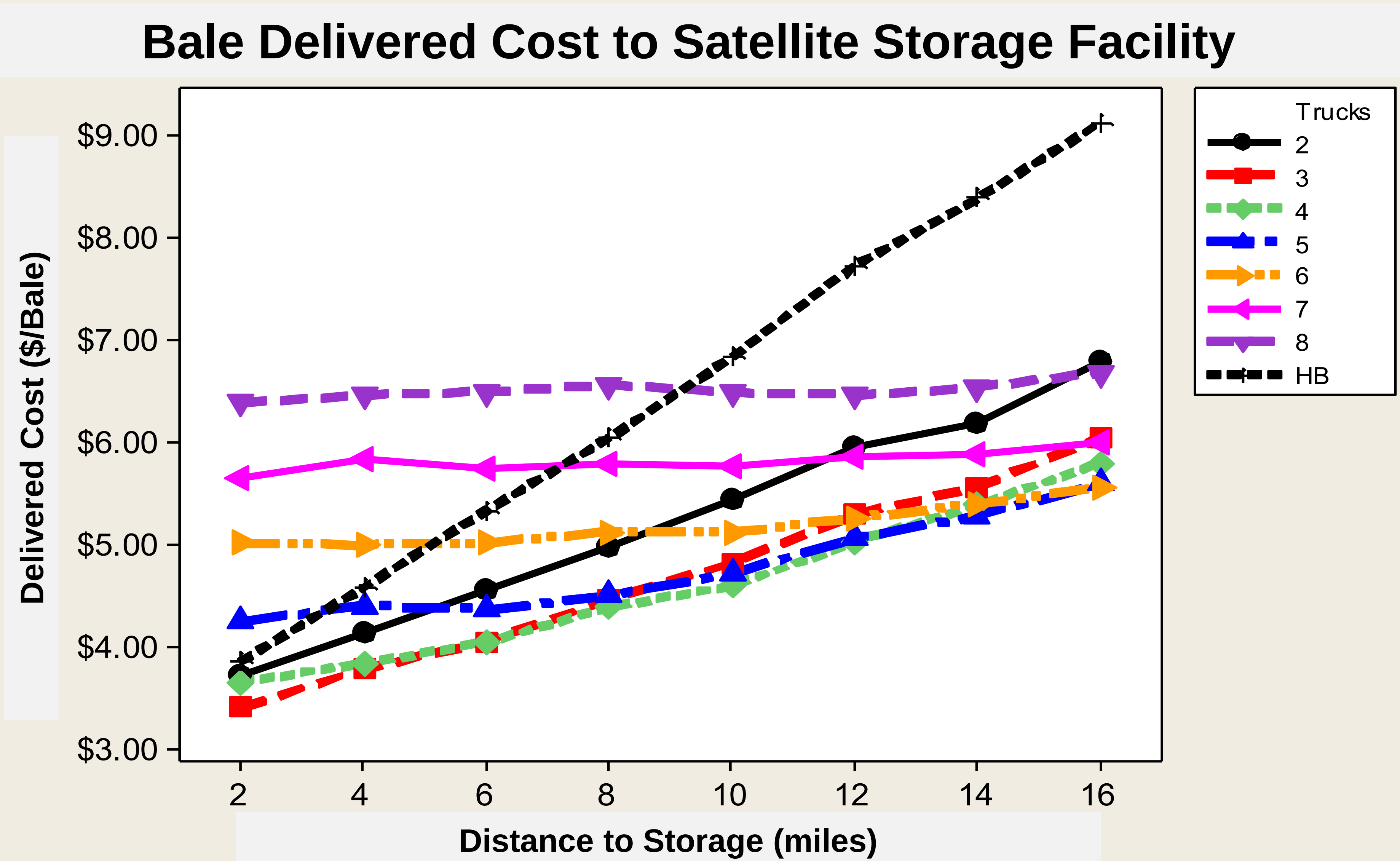
Bale Density Targets

- Theoretical max bale density is approximately 15 lb/ft^3
- Current achievable density on an industrial scale is 10.5 lb/ft^3
- Commercially optimized goal is achievable with a bale density of 12.5 lb/ft^3
  - Reduces bale handling requirement
  - Improves baler uptime
  - Reduces storage costs
  - Maximizes road transportation

Biomass Transportation

Bale Moving Dynamics

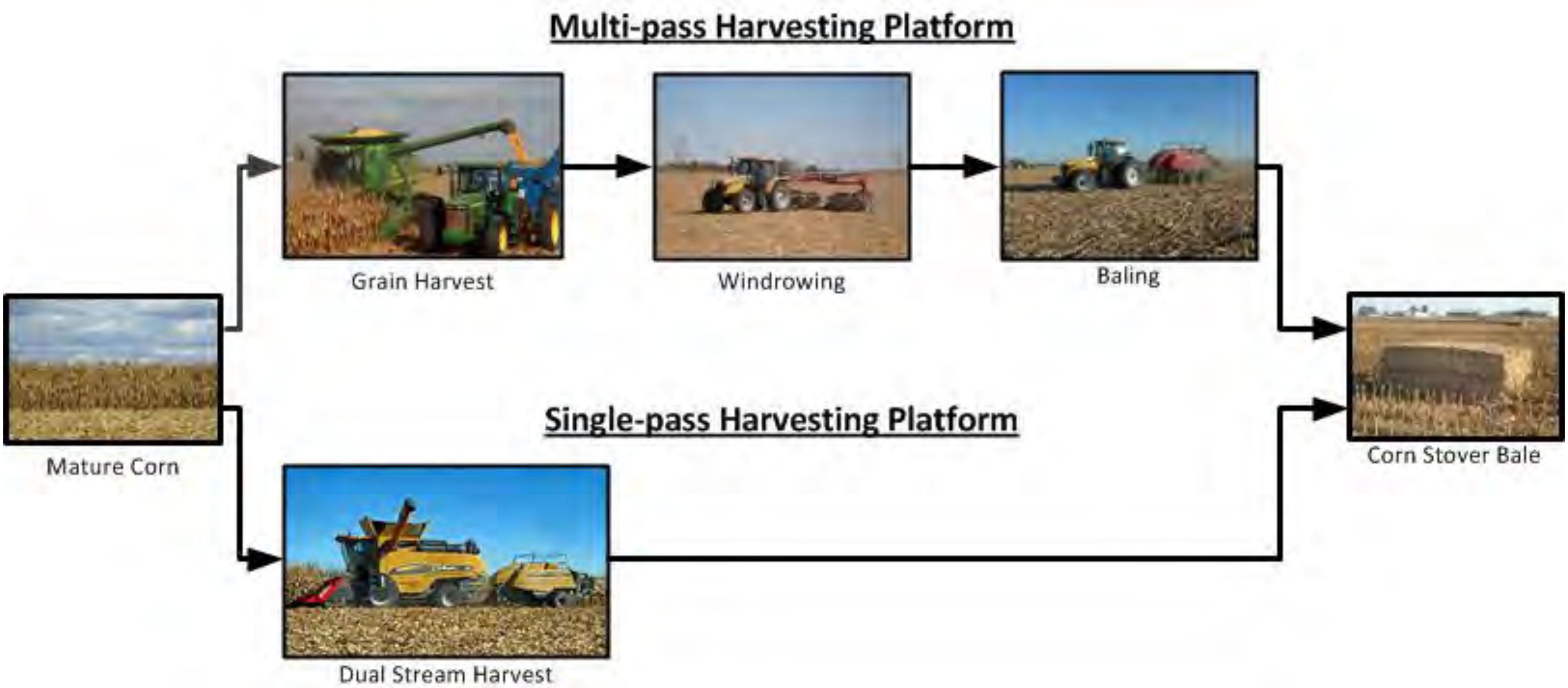
Transportation Team Optimization



Transformational Technologies

Biggest opportunities exist in harvest operations and improved bale density.

Advantages of Single Pass Baling



Single Pass Baling Systems

Biomass Economics

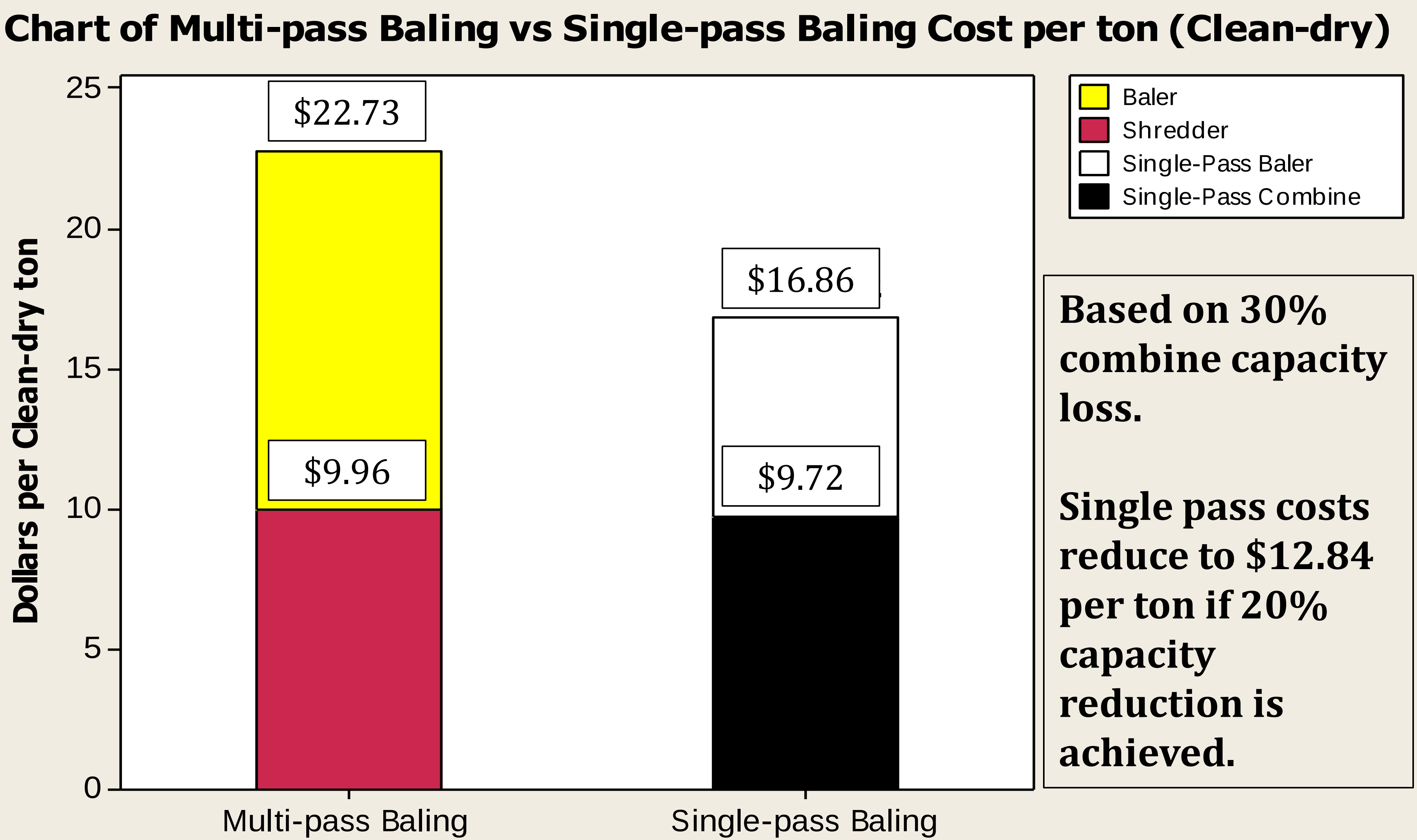
Equipment Requirements to Produce 18 ton/hr

1 Single Pass Solution

1 Baler + 1.4 Shredders

Production Cost Comparison

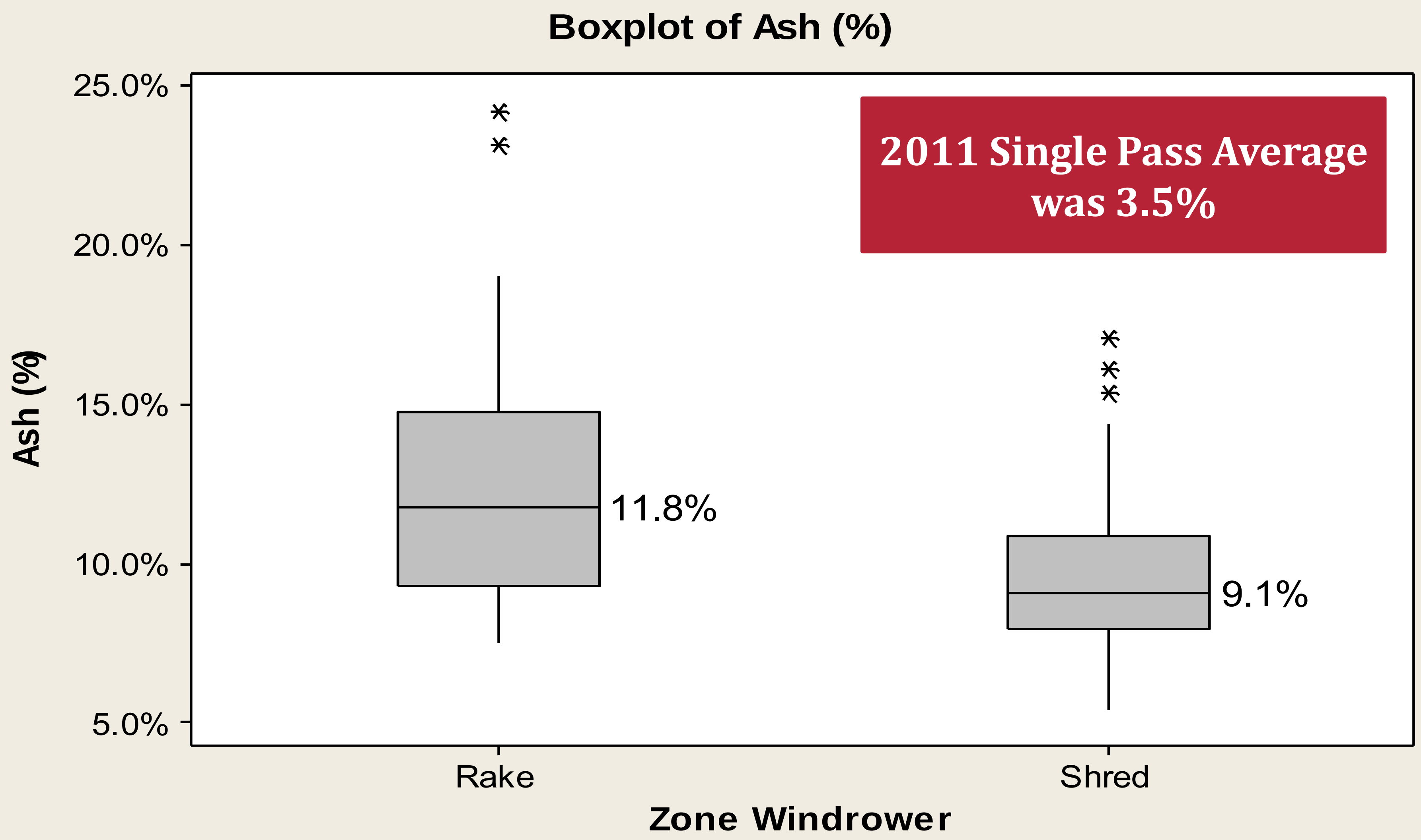
Boundary: Bale dropped in field



Based on 30% combine capacity loss.

Single pass costs reduce to $12.84 per ton if 20% capacity reduction is achieved.

Quality Improvements of Single Pass Harvesting



Mature Supply Chain Costs

Feedstock Development	Biomass Harvest	Collection Logistics	Biomass Storage	Delivery Logistics
$0/ton	$16/ton	$7/ton	$7/ton	$12/ton
~~$16/ton~~	~~$23/ton~~	~~$8/ton~~	~~$8/ton~~	~~$15/ton~~

High density single pass harvesting technology along with credits for residue management value of corn stover can yield $42/ton delivered cost.

Keys to Supplying 670,000 LSB per Year

- Know the system limits and operate at the edge of the limitation.
  - Limits may be biologically, environmentally, or economically driven.
- Educate operators on feedstock quality to minimize contamination of biomass.
- Operate in high density and high yielding areas. Machine and operational efficiencies increase with harvest rates.
- Standardize the densification format across the supply chain to maximize equipment utilization.
- Diversify storage systems to simplify at harvest activities and aggressively seek out options for storage locations.
  - Maintain sufficient industrial storage to supply the plant during harsh weather periods.
  - Leverage in-field storage to maximize machinery capacity.
  - Utilize ensiled storage for early harvest period.

Questions?

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