# DOE Bioenergy Technologies Office (BETO)
# 2015 Project Peer Review

## Design and Demonstration of a Comprehensive Biomass Feedstock Supply System

March 2015
Feedstocks Platform


Presented By: Kevin Comer
Antares Group, Inc.

Principle Investigator: Fred Circle
FDC Enterprises

# Goal Statement (Project Objectives)

Demonstrate all aspects of an innovative industrial-scale feedstock supply system for industrial-scale (>500,000 tons/year) biomass end-users.

- Cost reductions for large scale feedstock delivery estimated to be ~$13.00 per ton (conservative)
- Identify and measure economic costs for all stakeholders
- Support development of material quality and sustainability specifications

# Goal Statement (Project Objectives)

- Key equipment development
  - Improved Industrial Grade Baler
  - Self Loading Trailer
  - Bale Picking Truck
  - Single-pass Harvest Systems
  - Improved Header for Heavy Crops

**Self-Propelled Baler**

**Bale Picking Truck (BPT)**

**Heavy Crop Header**

**Single Pass Baling**

**Self-LoadingTrailer (SLT)**

# Quad Chart Overview

## Timeline

- Project start date: 9/1/2010
- Project end date: 6/30/15
- Percent complete: 95%

| Budget | Total Costs FY 10 –FY 12 | FY 13 Costs | FY 14 Costs | Total Planned Funding (FY 15-Project End Date |
|---|---|---|---|---|
| DOE Funded | $2,998,403 | $1,255,020 | $187,797 | $570,542 |
| Project Cost Share | | | | |
| Abengoa Bioenergy | $287,173 | | | |
| Allied Freeman | $1,394,178 | | | $294,723 |
| Antares Group Inc. | $0 | | | |
| Collaborators | $295,815 | | | $376,965 |
| FDC Enterprises | $154,129 | $41,711 | | $538,038 |
| Kansas State University | $69,248 | $36,184 | | |
| Kelderman Farms | $144,025 | | | $119,697 |
| Kelderman Manufacturing | $780,053 | | $6,801 | |
| Mendel Biotechnology | $145,094 | | | |
| TR Miles Consulting | | | | |
| Vermeer | $37,908 | | | |
| MacDon | | | | $269,911 |

## Barriers

- Barriers addressed
  - Ft-L. Biomass Material Handling and Transportation
  - Ft-M. Overall Integration and Scale-Up
  - Ft-D. Sustainable Harvesting

## Partners

- FDC Enterprises (Prime Contractor)
- Equipment Manufacturers:
- Kelderman Manufacturing
- Allied Systems / Freeman
- MacDon
- Assistance from others:
  - Vermeer, JCB, Rotochopper
- Abengoa Bioenergy (Initial End-User)
- Antares Group (Mgt. & Tech. Services)
- INL (Lab Analysis, Sustainability)
- Kansas State (Sustainability)

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FREEMAN A Division of Allied Systems Company | kelderman | ABENGOA BIOENERGY Science. Solutions. Service. | MacDon The harvesting specialists. | JCB

# Collaborative Development Team

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Vermeer | Prairie Lands Bio Products Inc Discovering solutions for the new millennium | ROTOCHOPPER Inc.

THE SAMUEL ROBERTS NOBLE FOUNDATION | INL | K-STATE Kansas State University | STAR BRAND SEED | Mendel

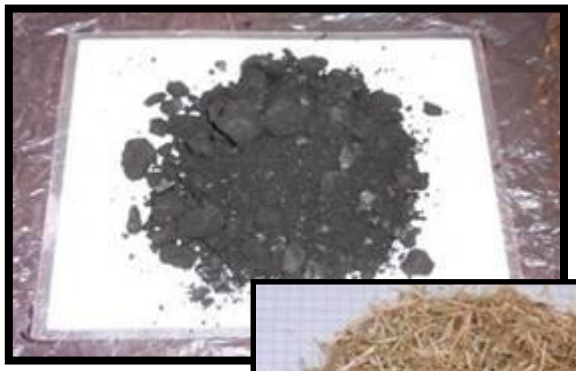
IOWA FARM BUREAU PEOPLE. PROGRESS. PRIDE. | Greenhouse Gas Services a GE AES venture | T.R. Miles Consulting Engineering Consulting | ALLIANT ENERGY | Show Me energy cooperative

# Project Overview

## TEAM GENESIS / BACKGROUND

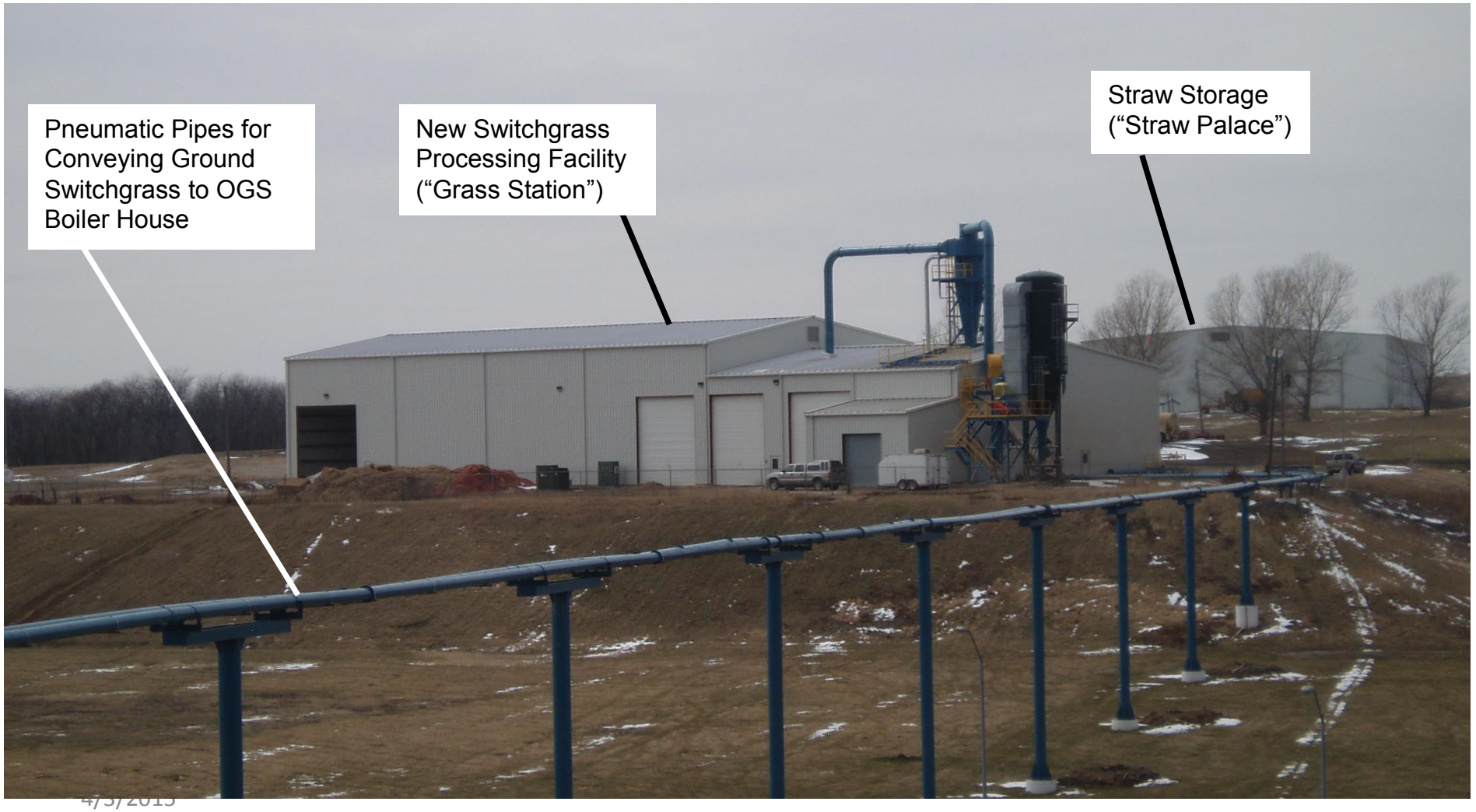
## Switchgrass Cofiring

## Ottumwa, Iowa

- Ottumwa Generating Station
  - Alliant Energy / Mid-American
  - 726 MW, PRB Coal, 1982 startup
  - Twin furnace T-fired PC boiler
  - 2.5 to 5% heat input from switchgrass, **12.5 to 25 ton/hr**
  - Separate biomass injection, 2 - 4 ports
- Fuel
  - 3’ x 4’ x 8’ switchgrass bales
  - 2-step milling process to 1/8” minus
- Current Project Plan based on Lessons Learned (Teaming, Equipment Needs)

# Project Overview (Team History)



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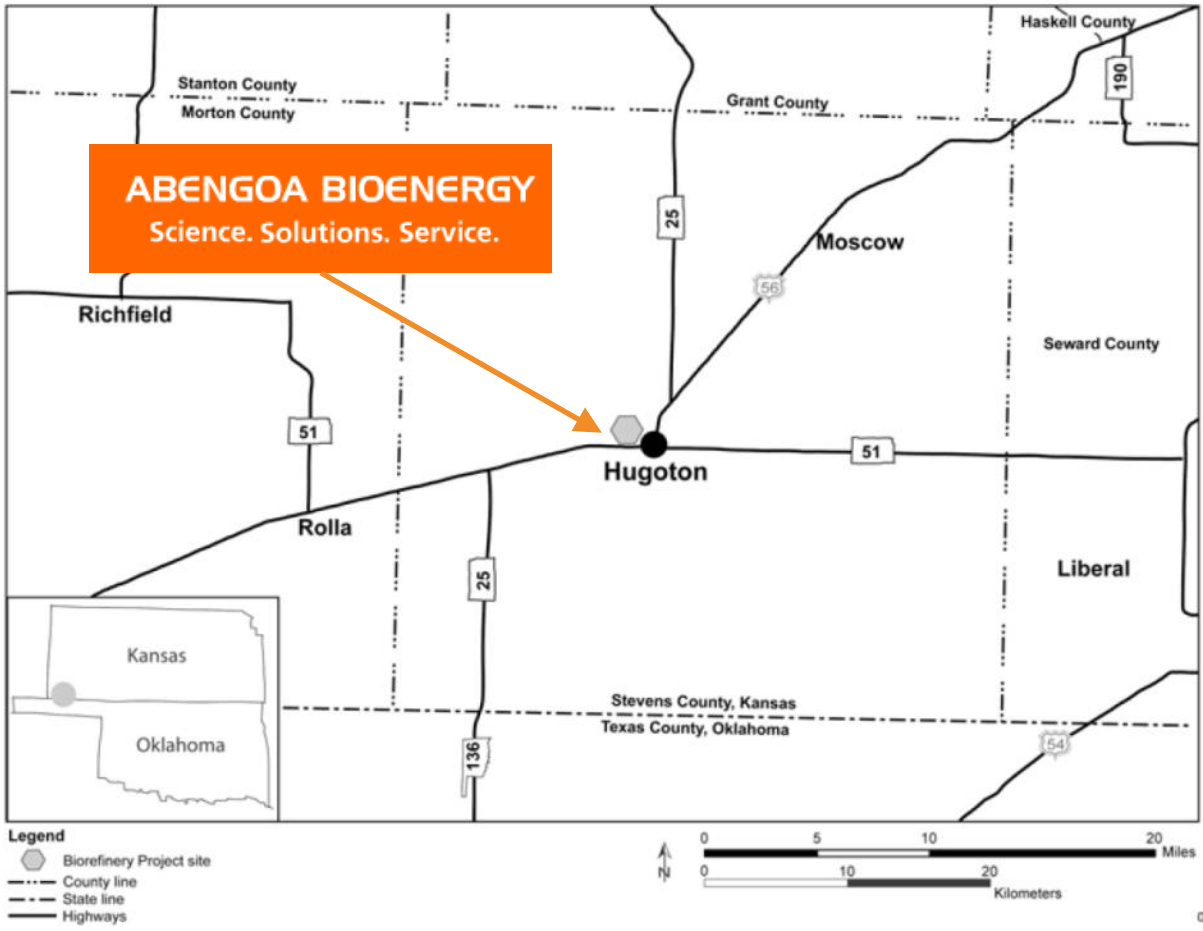
# Project Overview (Team History)

**Replacing up to 5% of this . . . .**

**with this . . . .**

# Initial Target System Application

- Feedstock Required:
  - ~560,000 ton/yr or more
  - ~ 80 or more deliveries per day
- Focus Feedstocks:
  - Corn stover
  - Wheat straw
  - Milo stubble
  - Energy crops (Switchgrass, Miscanthus, Biosorghum)



# Conventional Equipment (One Example)







Load Into Process Line

Transport


# Self Loading Trailer System

- Strategy Background
  - Concept based on decades of development and process evolution in the U.S. cotton and other industries
    - Everything is based on standard, proven, off-the-shelf equipment → **significant**
    - With ~~small~~ improvements and a new integration/application

# Proposed / Developing System

**Establishment**

**Single Pass Harvesting**

**Freeman 1592D Self-Propelled**

Removes one pass through the field

**Roadsiding**

**Bale Picking Truck**

Reduces # trips in the field by 67%

**Transport**

**Self Loading Trailer**

Removes loading and unloading operations

**Load Directly**

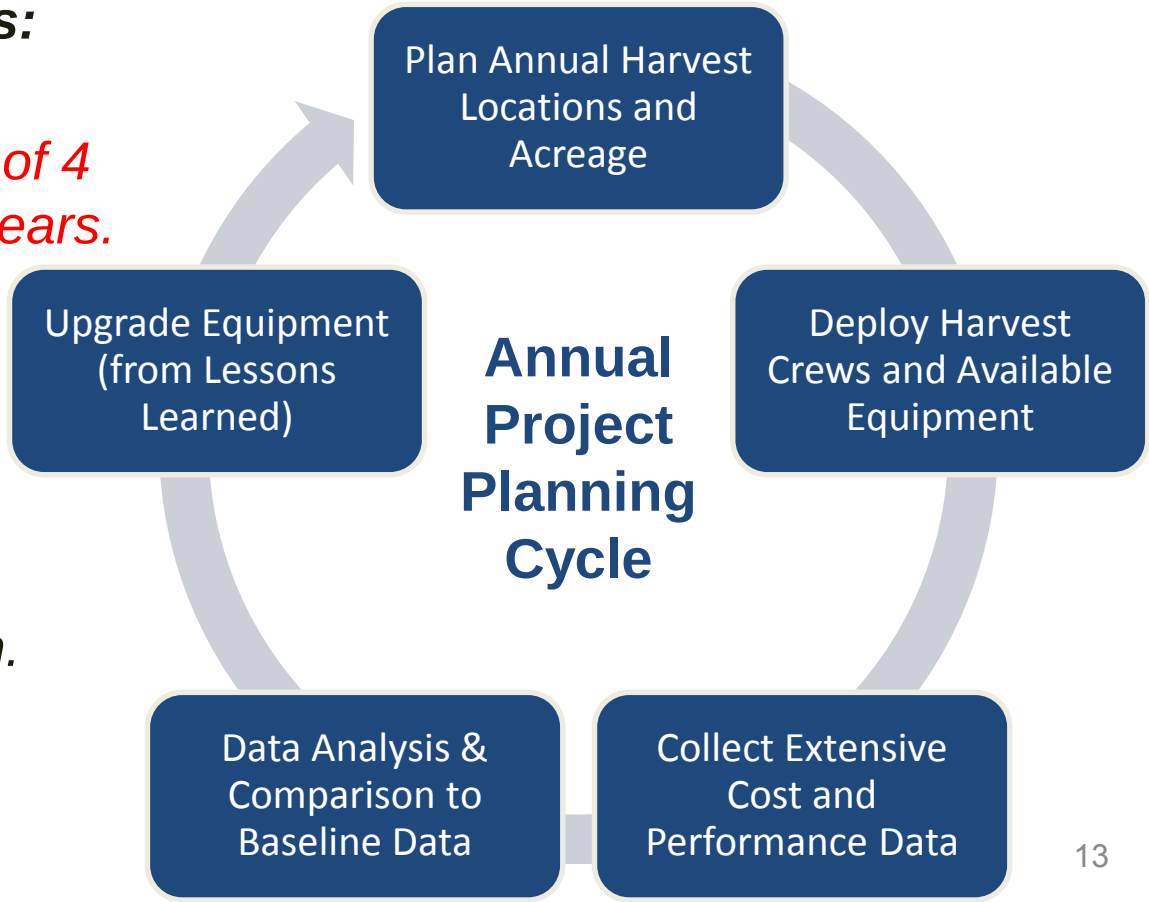
**Onto Process Line**

**Bale Yard Storage**

# 2 – Technical Approach

- ***Assembled a proven multi-disciplinary team, with complimentary capabilities to perform all required functions from crop establishment to delivery and processing at the end-use facility.***

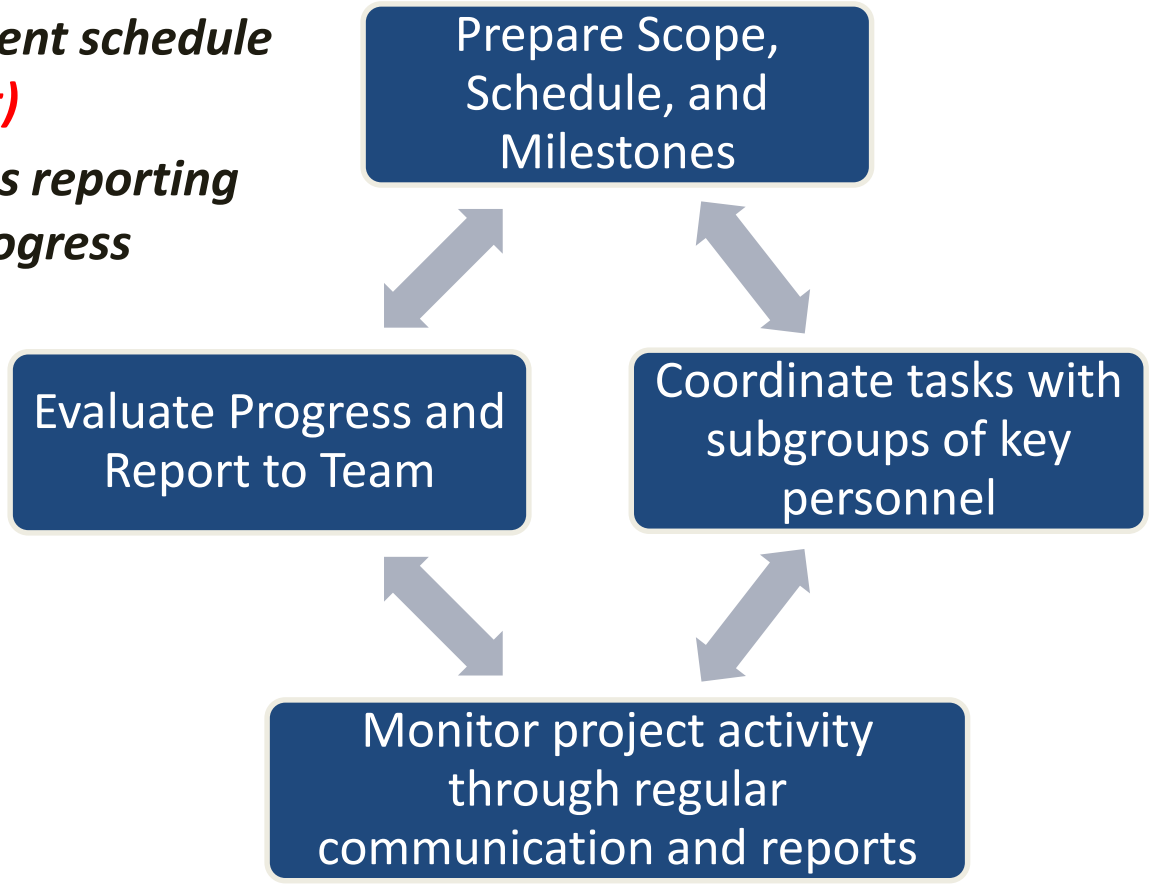
- ***Key Technical Challenges:***
- *Design, fabrication, and commercial demonstration of 4 new machines in under 3 years.*
- *Operations and logistics associated with annual demonstration harvests*
- *Accurate and reliable data collection methods to demonstrate cost reduction.*



# 2 – Management Approach

- ***Assembled a proven multi-disciplinary team, with complimentary capabilities to perform all required functions from crop establishment to delivery and processing at the end-use facility.***
- ***Planned equipment development schedule for 3 yr period. (and stuck to it)***
- ***Used DOE budget and progress reporting system to track and report progress***

- ***Key Management Challenges:***
- *Coordinating the project activities of over 15 companies across 5 project tasks.*



# 2 – Critical Success Factors

- Eliminate all possible separate operations
  - Mowing/conditioning, raking, trips through field
- Handle fewer pieces
  - Increase bale densities
    - Goal is to gross out a truck ( > 12 lb/ft$^3$)
  - Accumulate bales in field
    - Drop 2 or 3 from baler, in strategically good locations if possible (field side)
  - Modularize as soon as possible into truckload package
- Automate operations
  - Loading/Unloading onto trucks, and on process line

# 2 – Critical Success Factors (cont.)

- Reduce life cycle costs of equipment
  - Increase life and reliability
  - Reduce fuel use
- Increase biomass yields
  - Efficiently collect the maximum (sustainable) amount of biomass per acre
- Maintain quality control from start to finish
  - Pays huge dividends at processing facility
- Market and Business
  - Proven performance & value (Many thousands of tons)
  - Growing demand for high-tonnage biomass supplies

# 3 - TECHNICAL ACCOMPLISHMENTS/ PROGRESS/RESULTS

( Launch Video here )

# SYSTEM ANIMATION & INITIAL DEMONSTRATIONS

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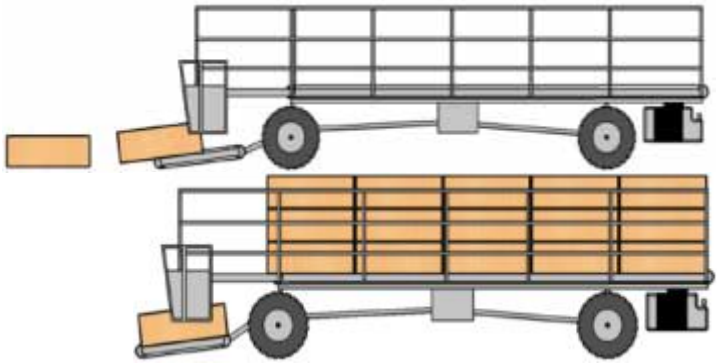
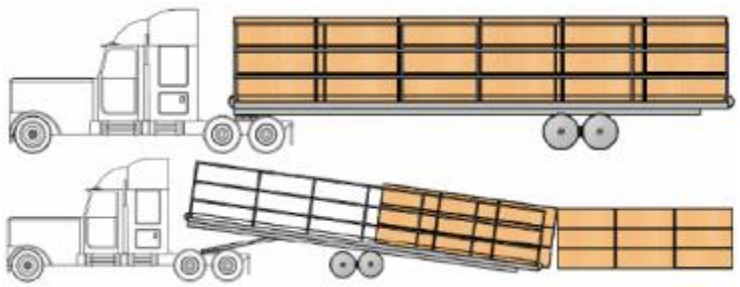
# We Have Come a Long Way…





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# Self-propelled Baler with Vermeer Basket Rake

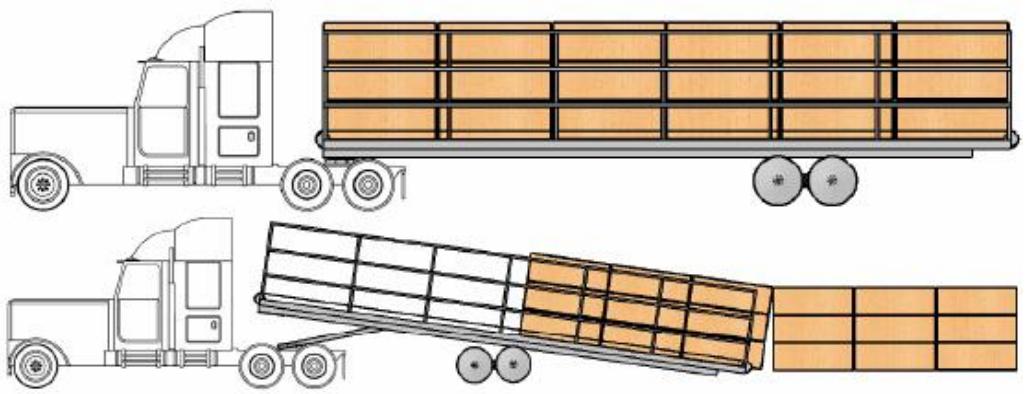


# Self Propelled Baler Progress

- Goals/Benefits:
  - ✓ – Eliminate 1 or more passes through field
  - ✓ – Demonstrate flexibility of SPB using different header/implements
  - ✓ – Bale densities from 11 & 12 lb/ft$^3$
- Continued Development:
  - Improved Bale Density
  - Dirt removal systems
    - "Passive" – gravity driven
    - "Active" – air assisted
  - Windrow merging header
  - Improved reliability (baler module)

# Self-Loading Trailer (SLT)

**THEN . . .**



**NOW . . .**

Fundamental Load / Unload Times (~5 minutes) and operation confirmed. Field demonstrations are ongoing.

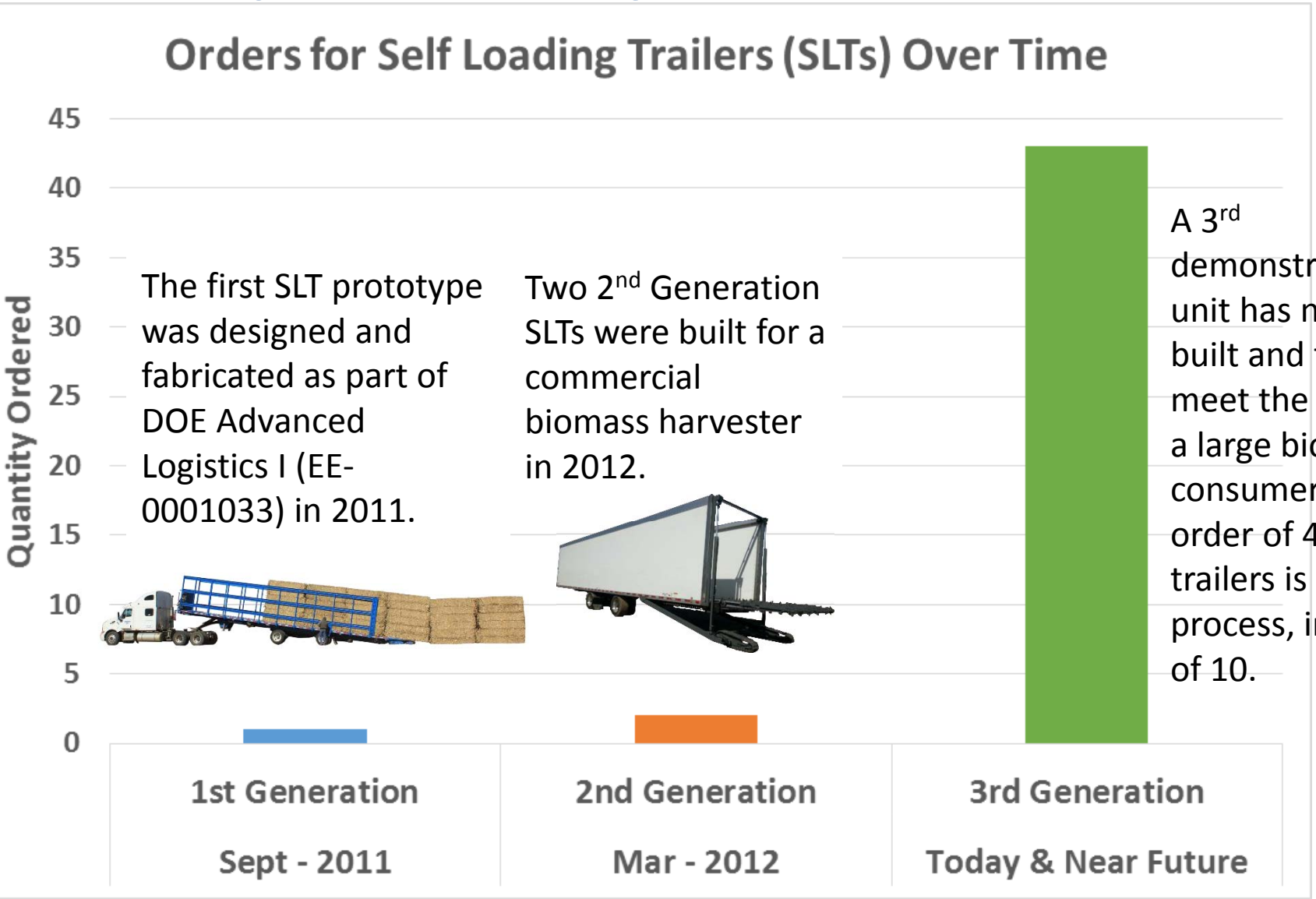
# Self Loading Trailer (SLT) Progress

- Goals/Benefits:
  - ✓ – Load/unload one "module" in 5 – 8 minutes
  - ✓ – Remove the need for additional loading/unloading equipment (some cases)
- Continued Development
  - 2nd generation SLT
    - Walking floor
    - Improved pickup
    - Lower loading angle
    - Low-friction solid walls
    - Backhaul capability for DDGs, treated feed

**1st GenerationSLT :**

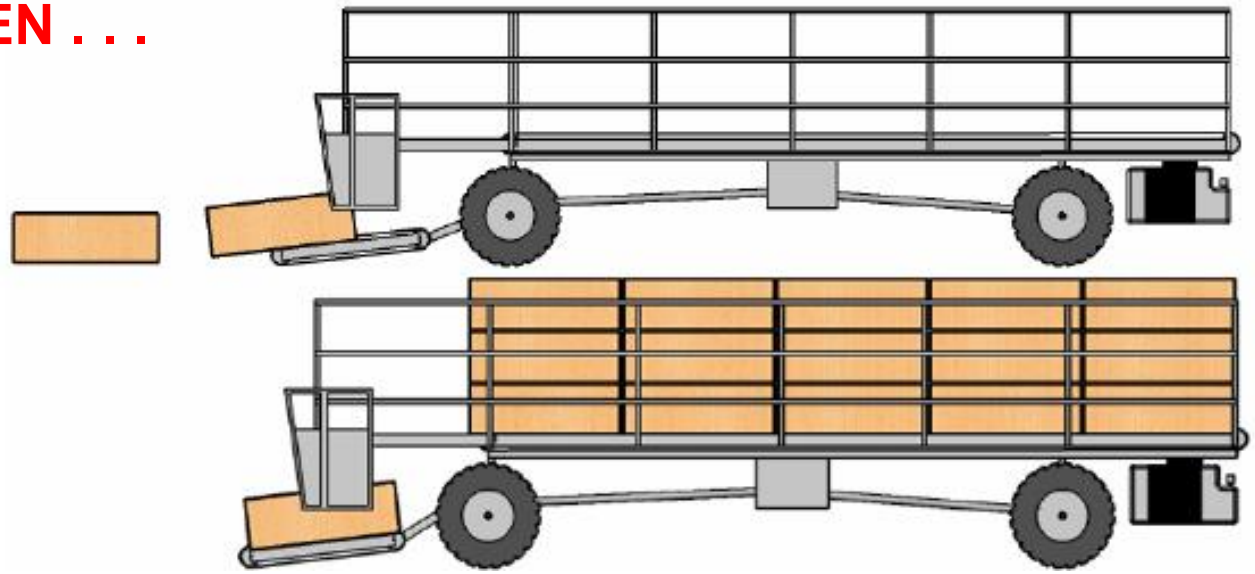
**2nd GenerationSLT :**

# Example of Early Commercialization



# Bale Picking Truck (BPT)

**THEN . . .**



Field demonstrations are ongoing.

**NOW . . .**

# Bale Picking Truck (BPT) Progress

- Preliminary tests have shown that it will provide considerable cost reductions in roadsiding operations
- Goals/Benefits:
  - Fewer trips through the field
  - Packages 36 to 42 bales into one "module"
  - Direct transfer to SLT fieldside
- Continued Development
  - Continued testing and demonstration is ongoing
  - Fundamental re-design to add stacking capabilities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# Heavy Crop Header (MacDon)

MacDon
The harvesting specialists.


MacDon has fully developed and demonstrated the prototype header and knows what needs to be done to take the next development step.

# Heavy Crop Header Progress

MacDon
The harvesting specialists.

- Goals/Benefits:
  - Heavy crop header can operate at 4 to 6 mph while conditioning crop well for efficient baler pick-up

- Continued Development
  - Implement design improvements into new prototype
  - On hold pending demonstrated market pull

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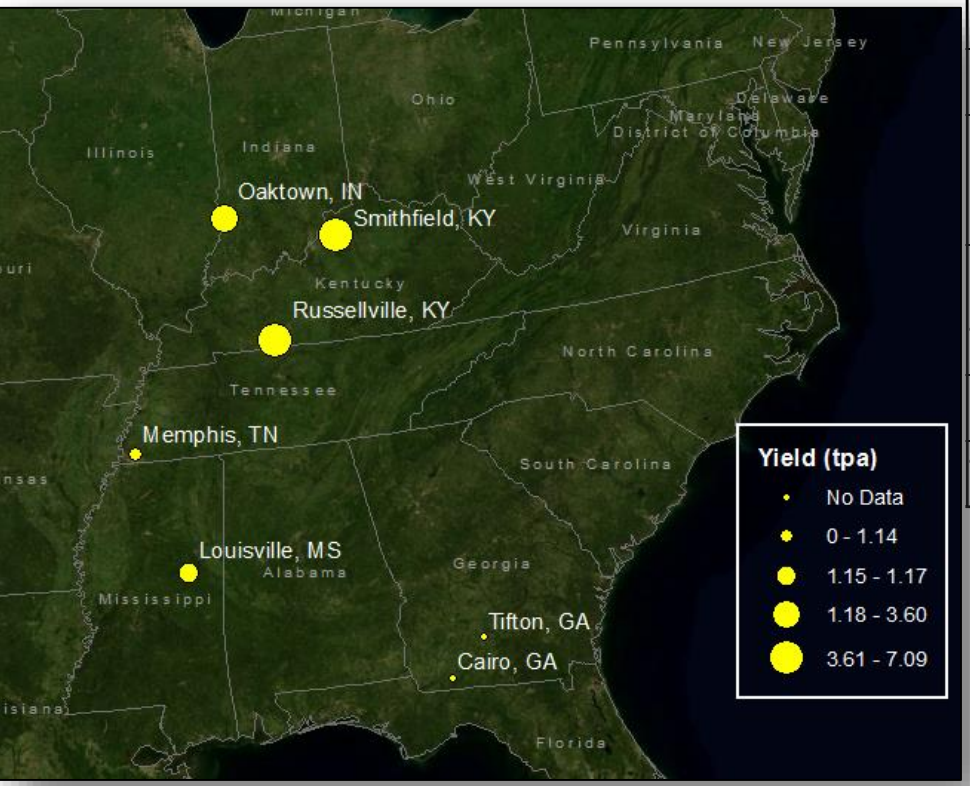
# Overview of Miscanthus Harvest Locations

## Miscanthus Harvest Field Summaries




| Location | Bale Count | Tons | Acres | Yield (tpa) |
|---|---|---|---|---|
| Russellville, KY | 672 | 461 | 65 | 7.1 |
| Smithfield, KY | 99 | 59 | 9 | 6.5 |
| Oaktown, IN | 28 | 18 | 5 | 3.5 |
| Louisville, MS | 44 | 28 | 24 | 1.2 |
| Memphis, TN | 13 | 8 | 7 | 1.2 |
| Cairo, GA | 34 | 8 | N/A | N/A |
| Tifton, GA | N/A | N/A | N/A | N/A |

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# Single-Pass Harvest System (FDCE)

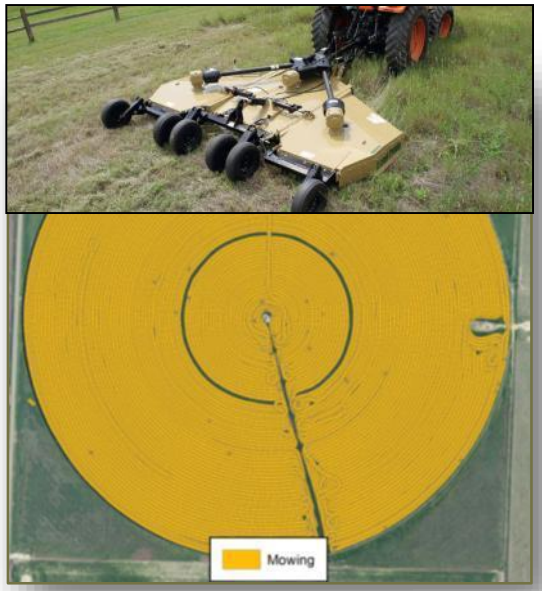


# Data Collection Activities

- Multiple rake / tractor / baler combinations
  - Field rates per operation
  - Time, labor, fuel requirements per operation
  - Maintenance issues / costs (including downtime)
- Bale properties (~10% of bales)
  - Ash (biomass + dirt)
  - Moisture
- GIS-Based System Development
  - Inventory mgt, chain of custody, GHG tracking, sustainability tracking & reporting

# Detailed Cost & Performance Data Collection

- Labor, Fuel, Equipment, Parts, Travel, Freight, Field Rates





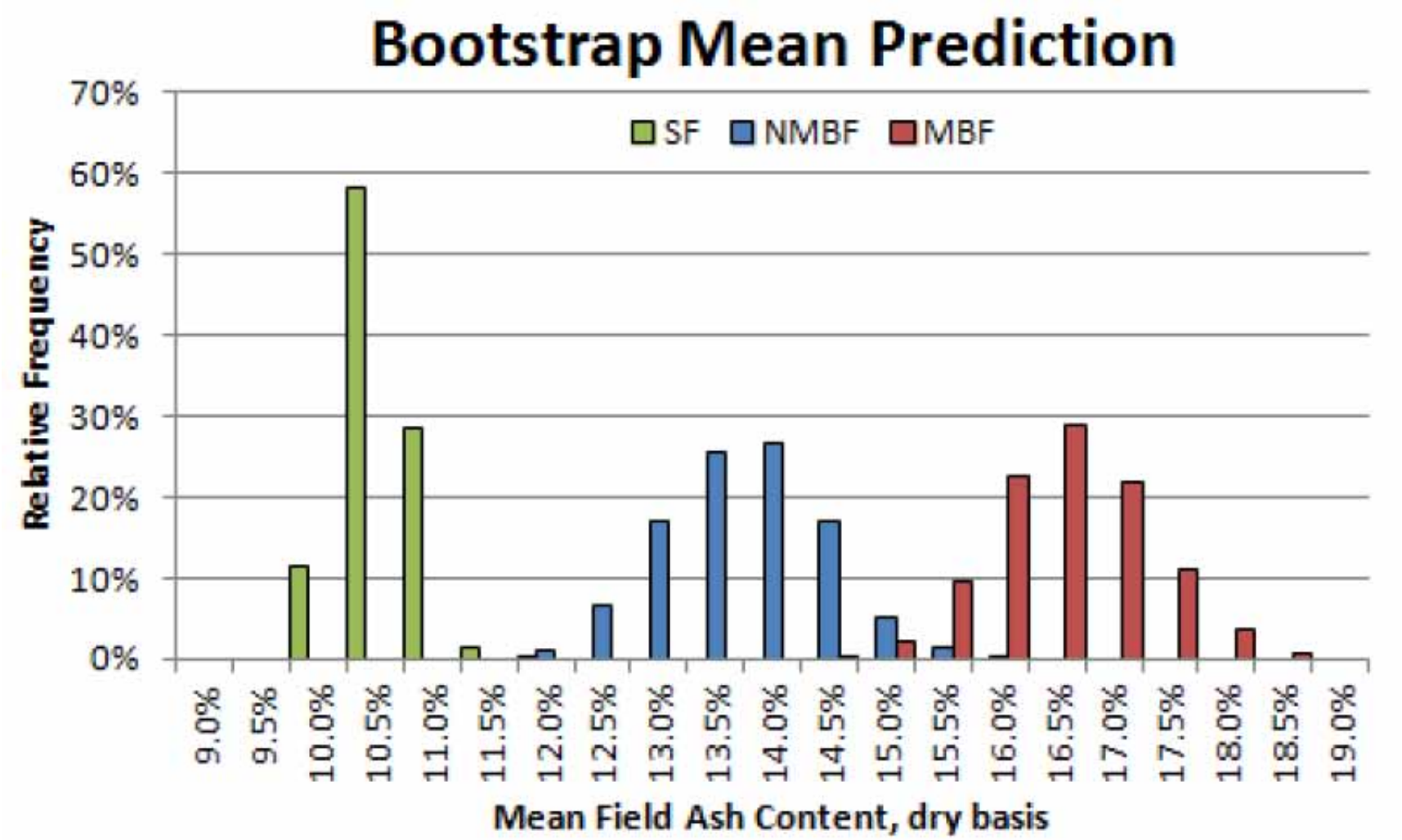

# Quality & Sustainability Data Collection

- Ash and moisture sampling for all harvest operations

- Active participation in sustainability standard development and trial implementation

# INL Ash Analysis

- 2011 Corn Stover harvest, Kansas



# Accomplishments to Date

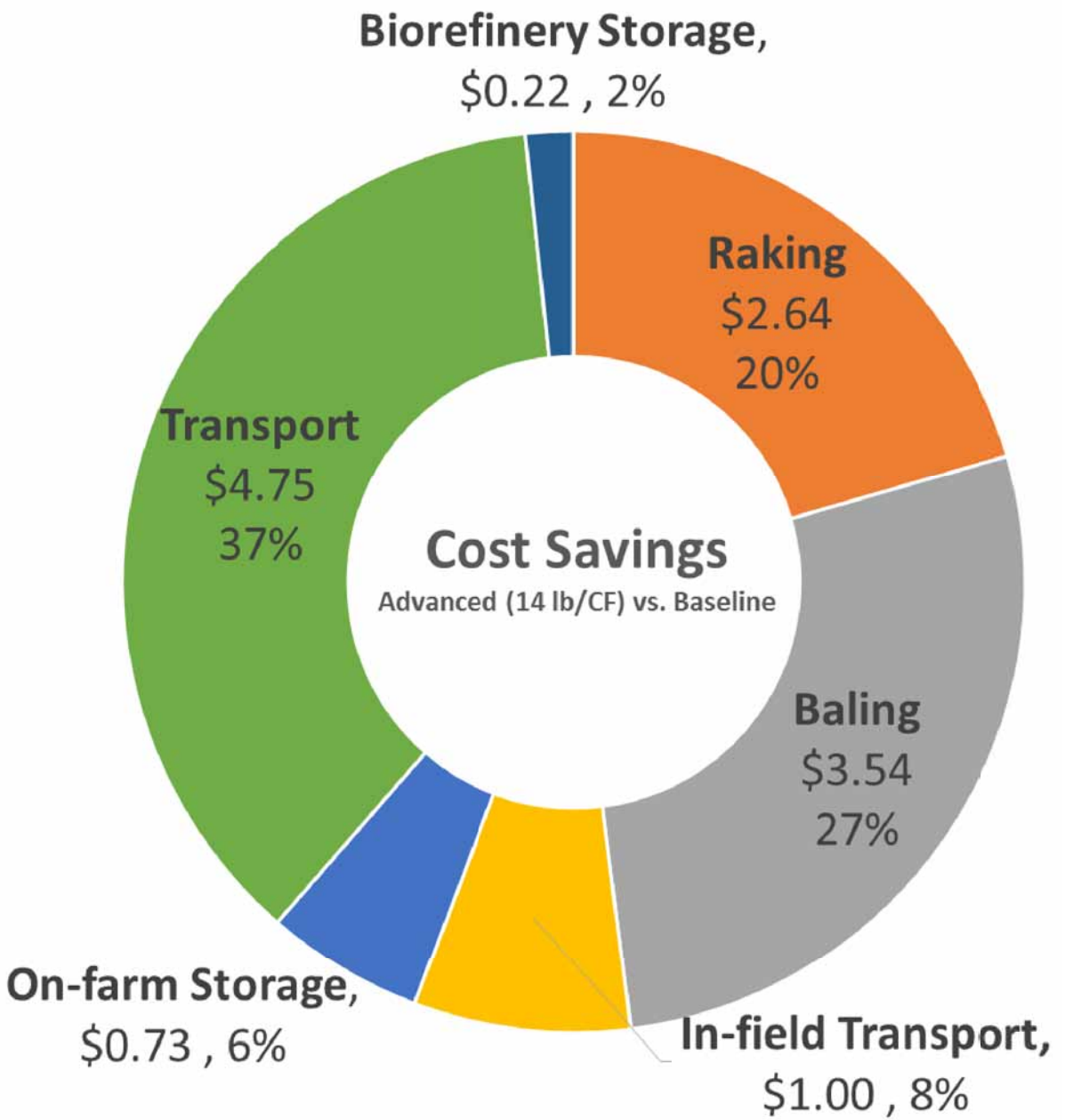
- All equipment fabricated and demonstrated
  - SPB: Removed one pass through the field
  - BPT: Required fewer trips through the field (vs. baseline) and packages 36 – 42 bales into one "module"
  - SLT: Loaded/unloaded a bale "module" in 5 – 8 minutes and removed the need for additional loading/unloading equipment
  - Heavy Crop Header: Operated at 4 to 6 mph in dense energy crops while conditioning crop well for efficient baler pick-up
- Collected performance/cost/quality data on all operations
- Measured baseline and advanced harvesting costs and performance
- Met cost reduction target ($13.00/ton) (modeled results)
- +~15,000 acres of corn stover and grasses harvested & extensive data collection & sampling

# Results of Independent Analysis

| | Baseline | | Advanced (11.5 lb/ft3) | | Advanced (14 lb/ft$^3$) | |
|---|---|---|---|---|---|---|
| **Operation** | **Cost by operation ($/dry ton)** | **Cumulative cost ($/dry ton)** | **Cost by operation ($/dry ton)** | **Cumulative cost ($/dry ton)** | **Cost by operation ($/dry ton)** | **Cumulative cost ($/dry ton)** |
| Combine | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 |
| Shredding | $3.98 | $3.98 | $3.98 | $3.98 | $3.98 | $3.98 |
| Raking | $3.96 | $7.94 | $1.32 | $5.29 | $1.32 | $5.29 |
| Baling | $12.82 | $20.76 | $9.90 | $15.20 | $9.28 | $14.58 |
| In -field transportation | $2.93 | $23.70 | $2.28 | $17.48 | $1.93 | $16.50 |
| On-farm Storage | $3.23 | $26.93 | $3.12 | $20.60 | $2.50 | $19.00 |
| Transportation (inc. loading/unloading) | $8.60 | $35.53 | $4.46 | $25.06 | $3.85 | $22.85 |
| Biorefinery storage | $0.77 | $36.30 | $0.67 | $25.73 | $0.55 | $23.40 |
| Grinding | $14.48 | $50.78 | $14.48 | $39.55 | $14.48 | $36.76 |
| **TOTAL COST** | **$50.78** | | **$40.21** | | **$37.89** | |
| **COST IMPROVEMENT** | | | | **$10.56** | | **$12.89** |

**Disclaimer**: IBSAL model is generalized for high-level (supply shed) modeling and is not designed for detailed analysis.

**Source**: Webb et al. (2013). *Simulation of the DOE High-Tonnage Biomass Logistics Demonstration Projects.* Oak Ridge, TN: Oak Ridge National


Biorefinery Storage,
$0.22 , 2%
Raking
$2.64
20%
Transport
$4.75
37%
Cost Savings
Advanced (14 lb/CF) vs. Baseline
Baling
$3.54
27%
On-farm Storage,
$0.73 , 6%
In-field Transport,
$1.00 , 8%

# 4 - Relevance

- The project's objectives align with the BETO's goals to provide biomass feedstocks at or below $80/DT.
  - The equipment developed under this project has demonstrated potential to help reach this goal.
- Independent modeling (IBSAL) verified that potential cost reduction goals ($13/DT) were accomplished.
  - This aligns with BETO's goals for "Terrestrial Feedstocks"
- Demonstrated ability to meet typical refinery quality specs for delivered bales
  - And some configurations that will *not* meet specs
- Tech Transfer/Marketability
  - Large initial order for trailers being filled now
  - Manufacturers own IP, will market and build

# 5. Future Work

- All critical project milestones have been accomplished. The project is now in the final data analysis and reporting stage and will officially end in June 2015.

- Final deliverables include:
  - Final performance/cost analyses and reporting

- Equipment OEMs will continue to upgrade and improve the equipment to meet the needs of the industry.
  - Will be a function of demonstrated performance, supplemental R&D funding availability, market demand
  - Part of another on-going DOE project

# Summary

1. Approach:
   - Design, build, test, improve, re-test. Measured performance & costs.
2. Accomplishments:
   - All equipment developed and demonstrated, improvements ongoing
   - Significant equipment performance and biomass quality data collection
3. Relevance:
   - Significant cost reductions and reliability improvements are needed in feedstock delivery systems—primary focus of this project.
4. Success Factors and Challenges
   - Success Factors: Market pull/growth, proven value on many tons, More R&D
   - Challenges: More heavy crop acres needed, more demonstration activities needed, continued refinement of equipment, continued efforts to reduce dirt
5. Future Work/Technology Transfer
   - All project objectives have been satisfied
   - Final project tasks include final performance/cost analyses and reporting
   - Equipment manufacturers are undergoing commercialization
     - Rate will be a function of demonstrated performance, supplemental R&D funding availability, market demand