BALES Biomass Alliance for Logistics Efficiency and Specifications

BALES Project Overview and Harvest Data Collection Progress, Plans, and Issues

ORNL Seminar

June 30, 2015

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Antares Group, Inc.

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

Presentation Objectives

- Provide high level overview of project activities and objectives
  - Square and round bale logistics systems
  - Feedstocks: Corn stover, switchgrass/WSG, wheat straw
  - Biomass pre-processing development and demonstration
  - Rapid in-field NIR-based quality analysis
  - Sustainability analysis and data collection

- Introduce harvest data collection presentation

BALES Biomass Alliance for Logistics Efficiency and Specifications

Project Summary

- 3 Year Development and Demonstration Project, Began Sept 2013
- Develop and demonstrate new and improved harvest and processing technologies that will reduce biomass supply chain costs while meeting quality specifications of biomass end users

FDC Enterprises Grasslands Services

POET Energy inspired.

ANTARES Group Incorporated

Vermeer

CLARIANT

B Hames Consulting

Pellet technology

kelderman

ADM

AGSOLVER

Biomass Toolbox

Biomass Market Access Standards (BMAS) Group

MacDon

MONSANTO

IOWA FARM BUREAU PEOPLE. PROGRESS. PRIDE.

IOWA CORN

INL Idaho National Laboratory

ASD Inc.

VT

Goal Statement

- To develop and demonstrate new and improved harvest and processing technologies that will lower biomass supply chain costs to $53/DT (harvest and transport to "throat of conversion reactor") while improving feedstock quality, validate improvements and remaining gaps, and address key sustainability issues in order to promote a sustainable and scalable advanced biofuels industry.

- Cost reductions for advanced large scale feedstock delivery and processing estimated to be ~$18 per ton (conservative)
  - Worth $5.4 million/yr at 300,000 ton/yr scale
- Identify and measure all supply chain costs.
- Improve feedstock quality measurement through NIR spectroscopy, relative to the end-users' specifications.
- Successful demonstration of these technologies in a commercial environment will support the increased production of cellulosic ethanol in the United States.

All project objectives support key DOE BETO objectives.

PROJECT BACKGROUND AND OVERVIEW

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Project Overview (Team History)

FREEMAN
A Division of Allied Systems Company

kelderman

ABENGOA BIOENERGY
Science. Solutions. Service.

MacDon
The harvesting specialists.

JCB

Project #1: Design and Demonstration of a Comprehensive Biomass Feedstock Supply System

FDC Enterprises
Grasslands Services

ANTARES
Group Incorporated

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

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Project Overview

Seeking to replace this…

(Team History)

Load Into Process Line

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Project Overview

With this…

(Team History)

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

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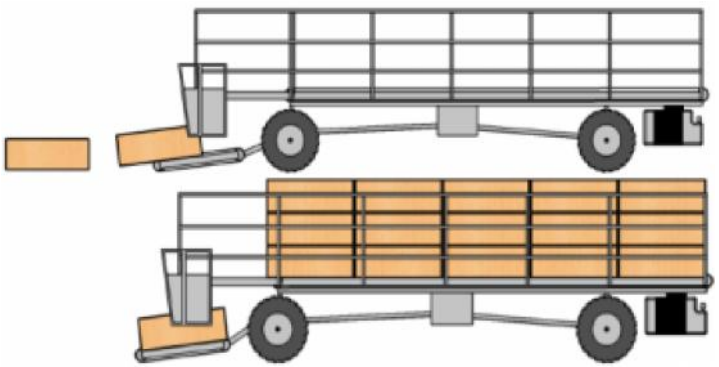
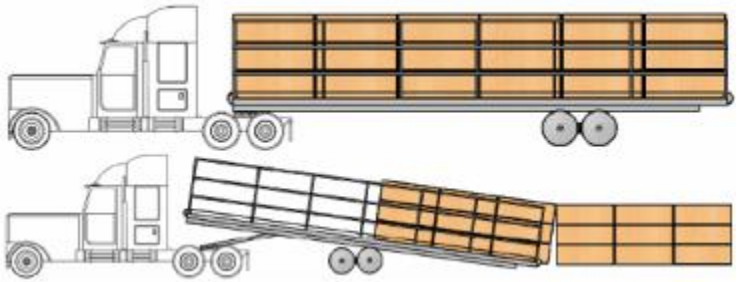
Project Overview

(Team History)





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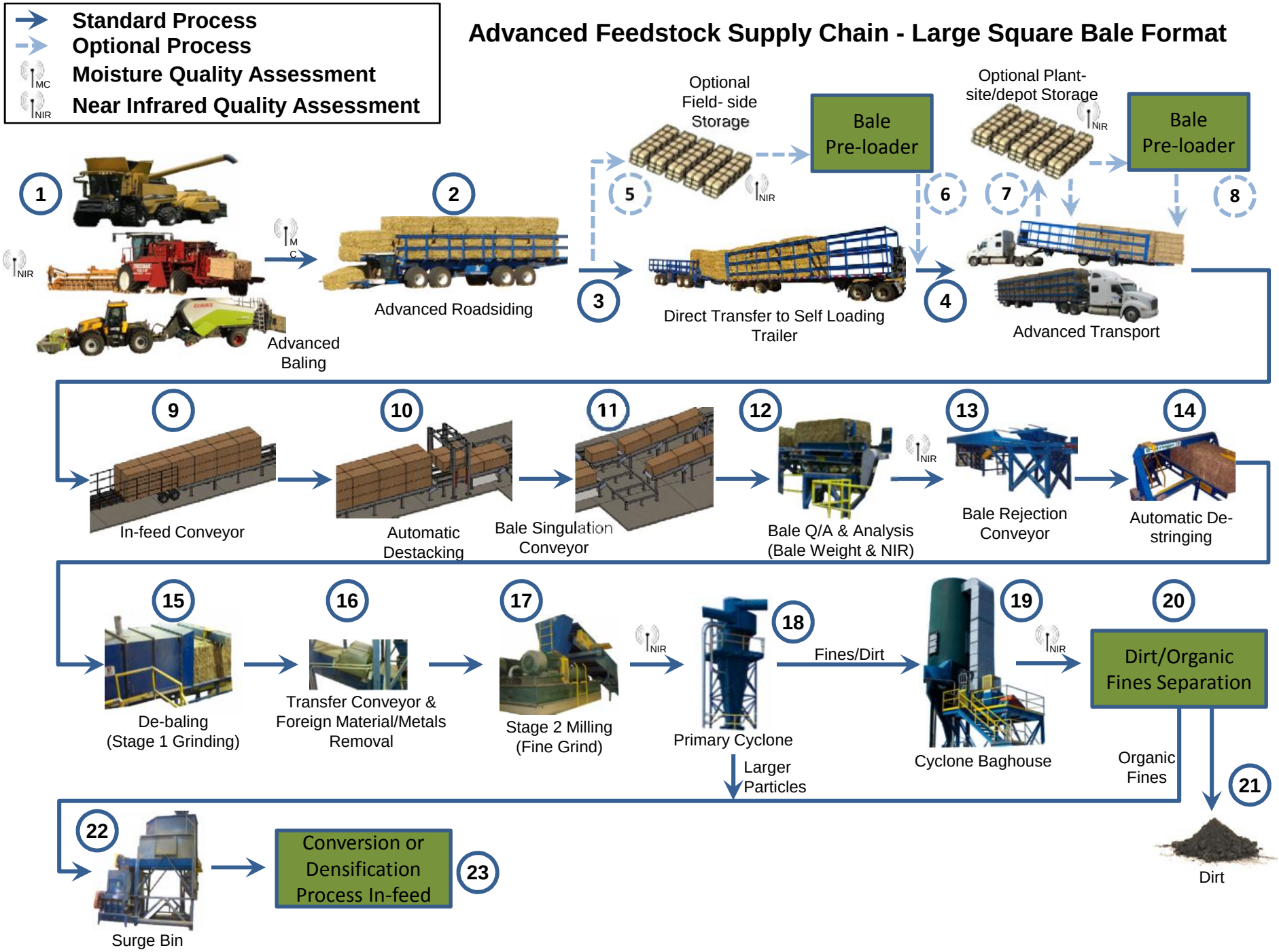
Poet-DSM's Project Liberty – Emmetsburg, IA

Advanced Feedstock Supply Chain - Large Square Bale Format



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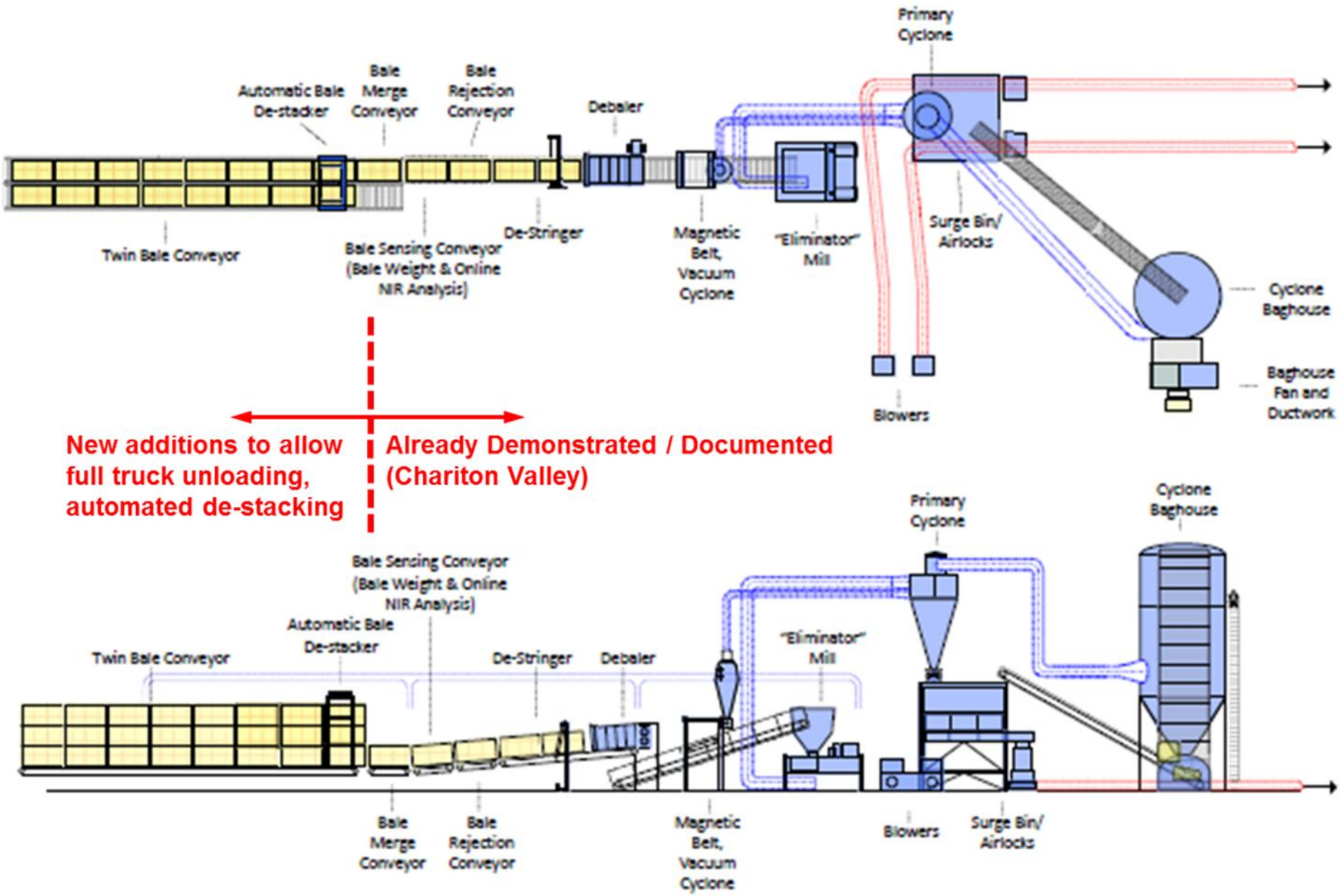
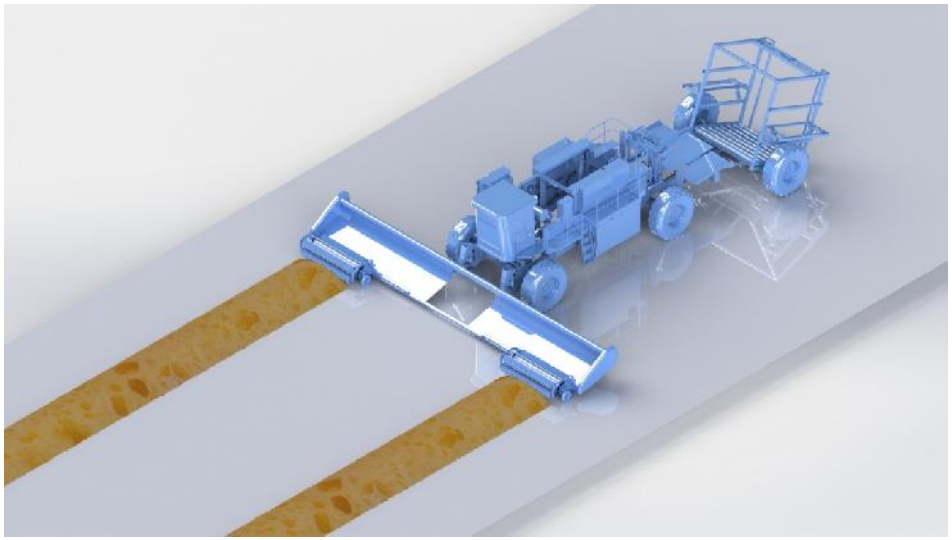
Process Line Concept Drawing

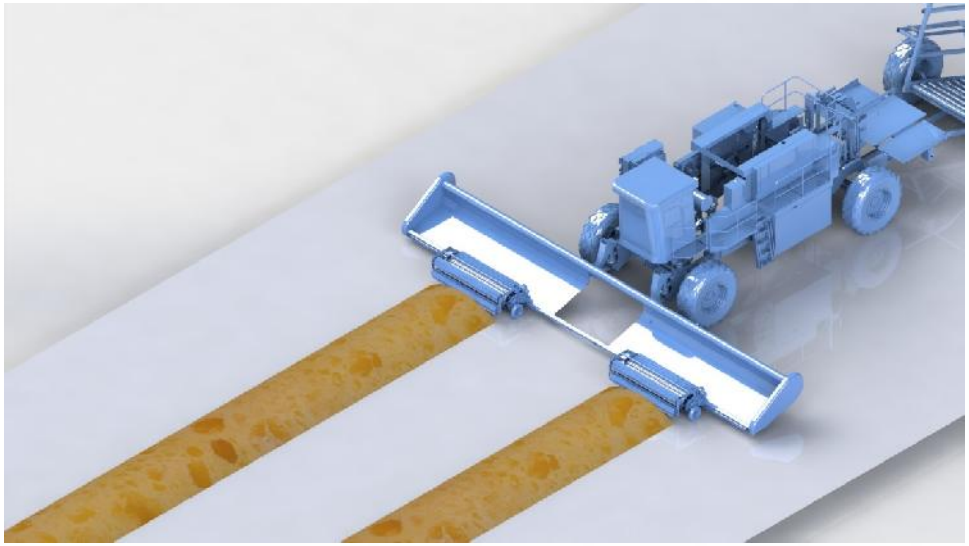


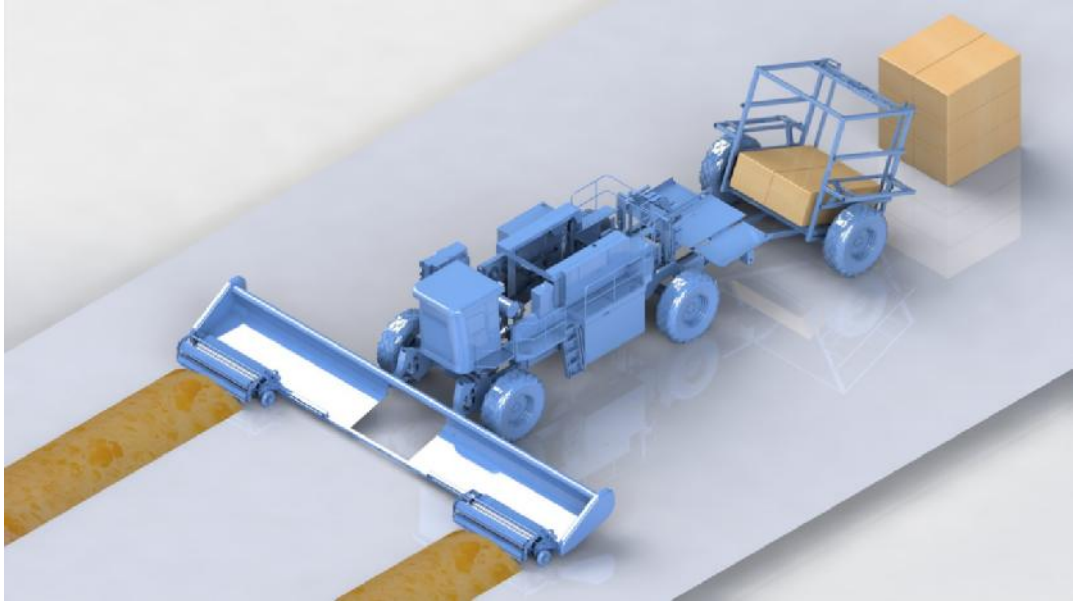
Kelderman "Projects"

- Self-Propelled Baler
  - Wind Row Merger
  - 6-Pack Stacker
- Pre-Loader
- Biomass Handling Trailer
- Bale-Picking Truck
- De-Stacker

Kelderman SPB, Windrow Merger, 6-packer







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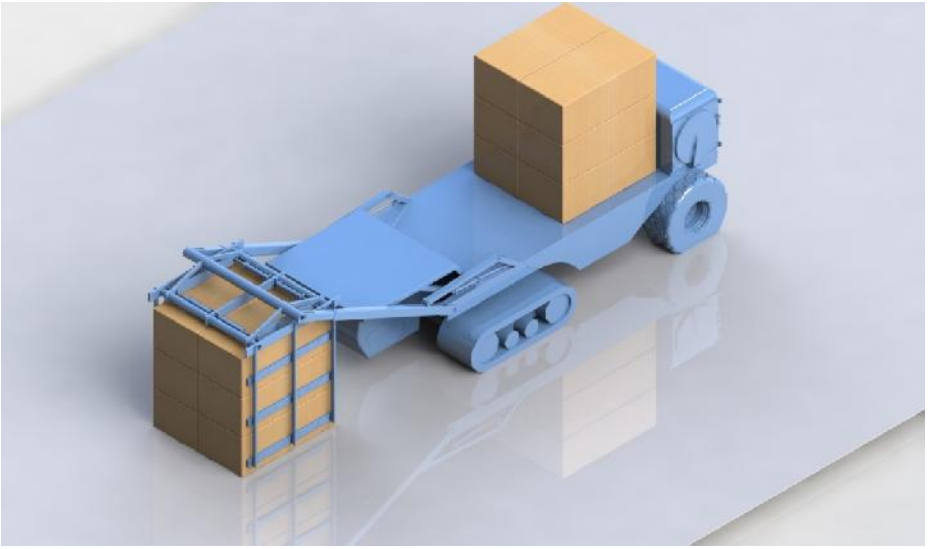
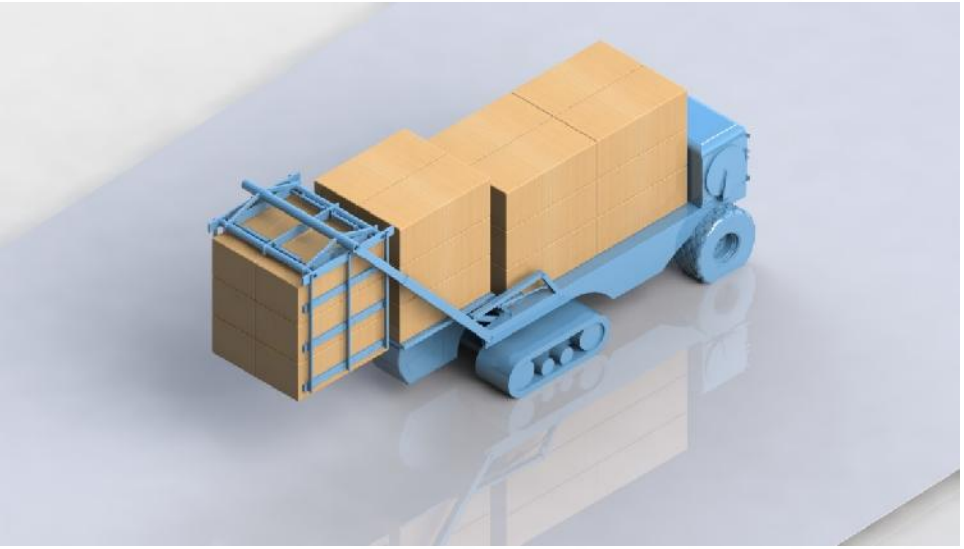
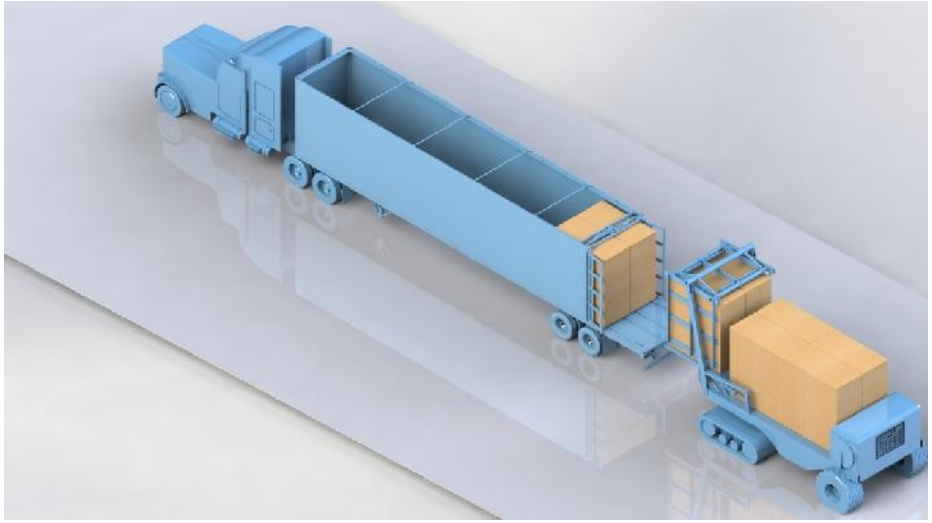
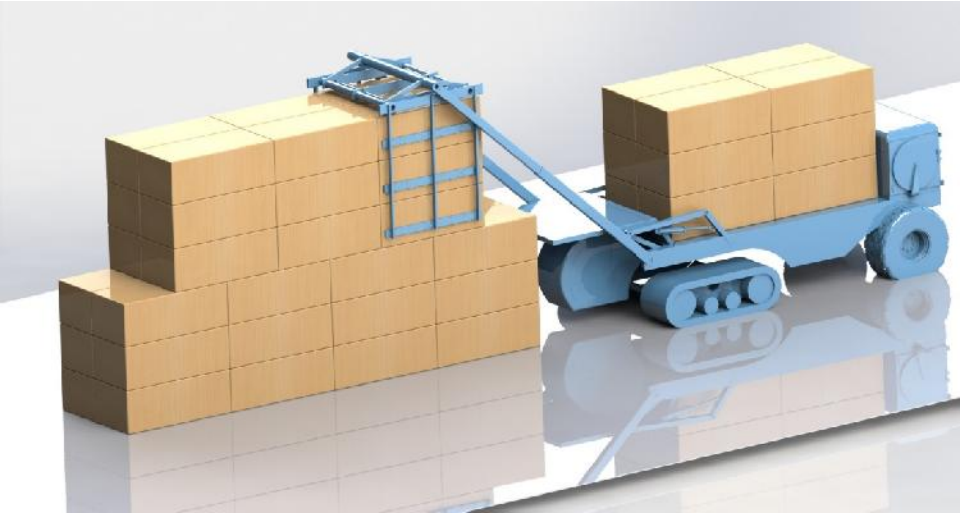
Kelderman Pre-Loader









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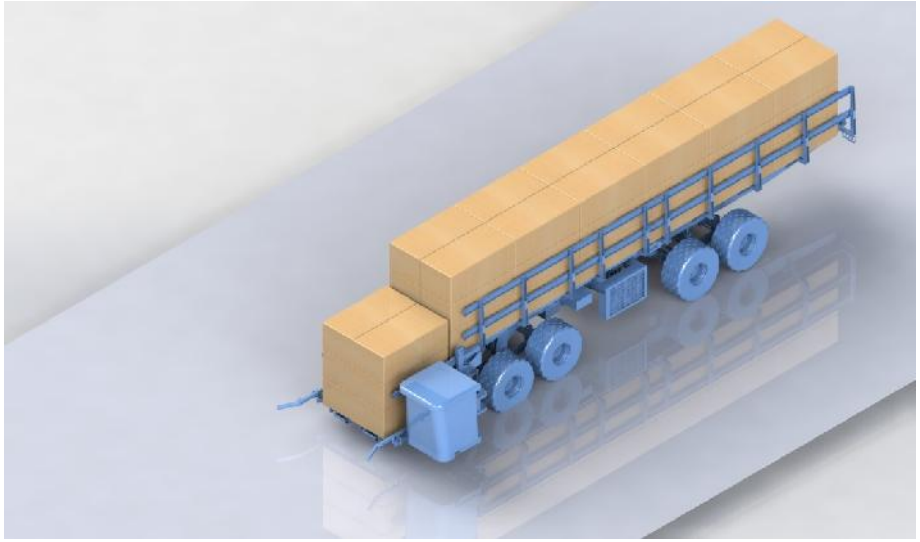
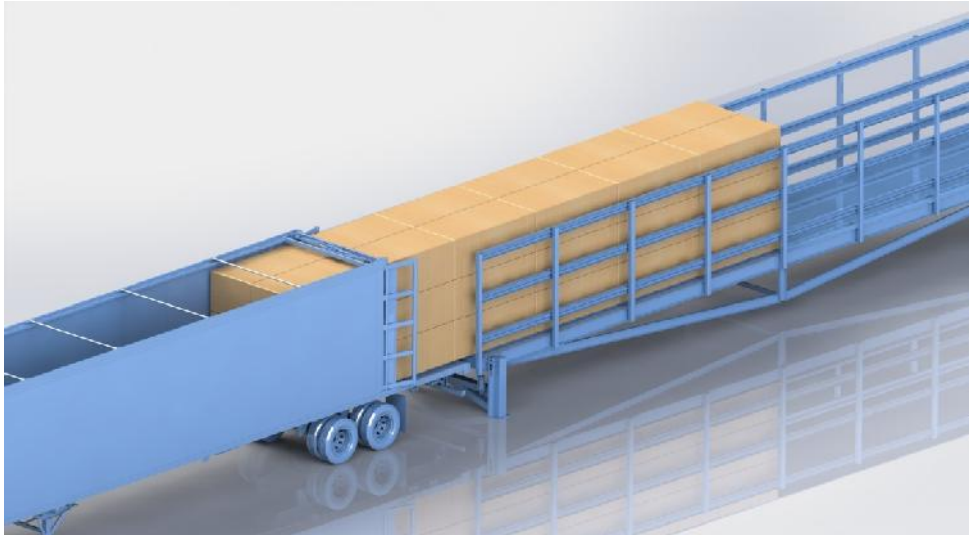
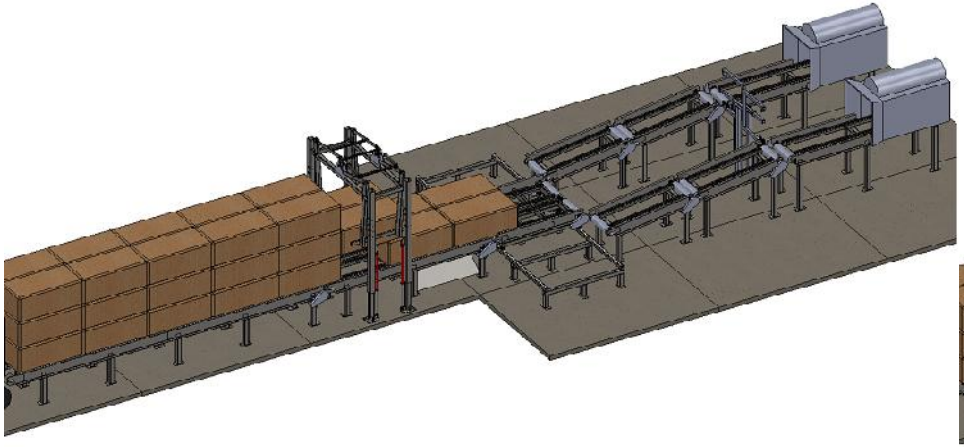
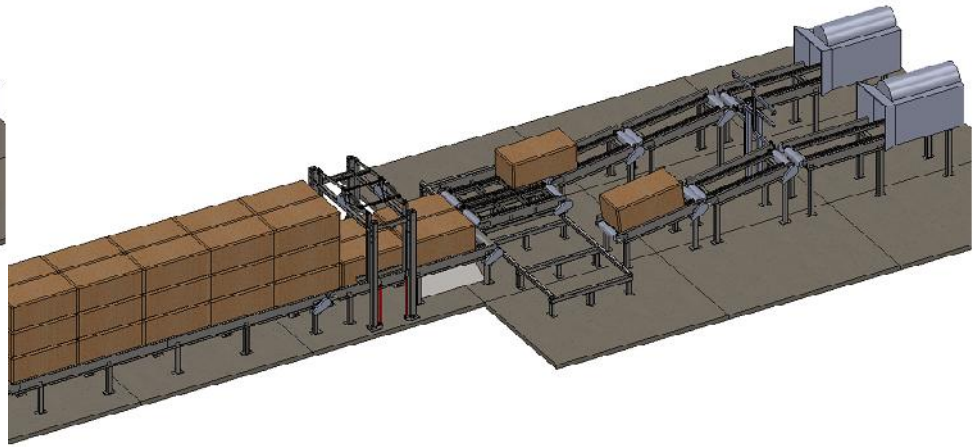
Bale-Picking Truck, Biomass Trailer, De-Stacker









EXAMPLE PROJECT DEMONSTRATION VIDEOS

Vermeer "Projects"

- Forage segment
  - Round bale harvest cost analysis
  - High capacity bale mover
  - Road transportation
  - Bale density
  - Reduce ash content in bale harvest
  - Reduce baler downtime
- Environmental segment
  - BG480 shredder
  - Bale shear
  - Automated de-baler system
  - Grinding/shredding improvements
  - Biomass shredder

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Automated De-baler / Net Wrap Removal System

- Tested various methods for cutting the net wrap
  - Considered parameters such as: Dust generation, wear life, energy consumption and reliability.
  - Plan to integrate the net wrap cutting function with the bale deconstruction device.
- Investigated methods for removing net wrap once it has been cut
  - More than 30 tests have been conducted
  - Want to capture the net wrap without retaining excess feedstock
- Brainstormed more than 20 different methods for de-constructing a round bale
  - Focused on using the simplest/most reliable mechanism
  - Built several prototype components:

Net Removal Device

Shearing Mechanism

Overall System

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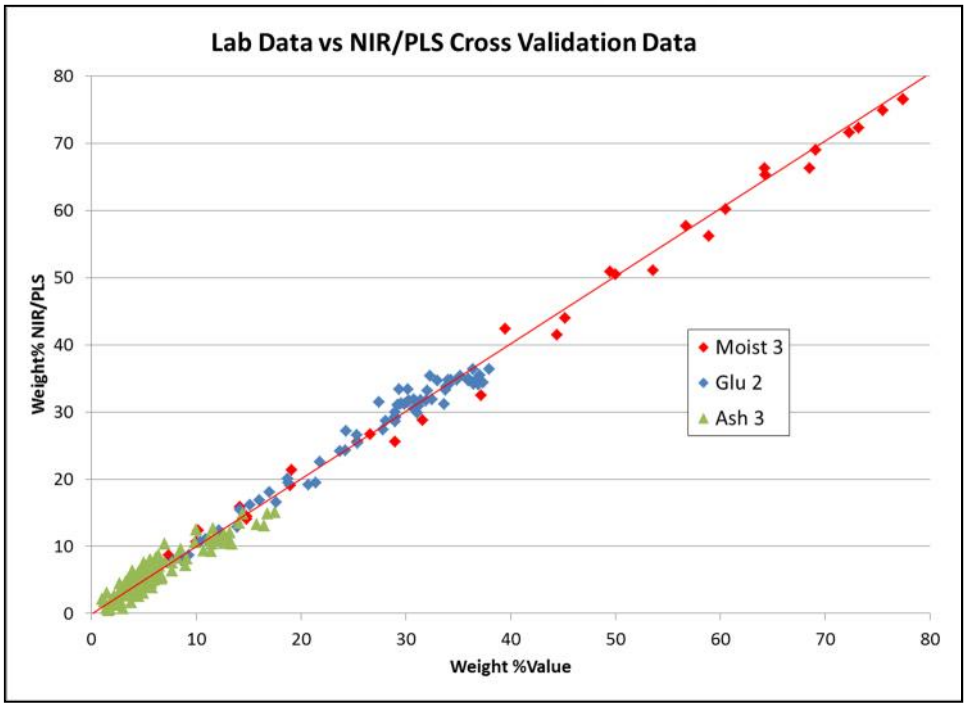
Bale Probe Design and Calibration

NIR/PLS Model	Moist 4	Glu 2	Ash 3
Cal. Range (%)	4 - 80	5 - 40	0.5 - 19
RMSECV (%)	2.4	1.5	1.3
Factors	2	3	5
R^2	0.989	0.969	0.850
N	33	68	162
Moist. Range (%)		4-80	4-80



- ASDI, INL and BHC have designed and calibrated a NIR Bale Probe accessory for the ASDI Field Spec.
- Prototype methods have been developed for the measurement of moisture, ash and glucan in corn stover.
- Recent method updates allow for analysis of samples with high moisture levels
- Glucan 4-60 %M and Ash 4-70 %M

Objectives of Harvest Data Presentation

- Describe harvest data collection activities and methods
- Summary of initial results
  - Machine / operation productivity
  - Harvested biomass characteristics
  - Fuel use
  - Measured/Estimated costs by operation
- Summary of future plans

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Harvest Data Collection & Results to Date

June 30, 2015
Antares Group, Inc.

ANTARES Group Incorporated

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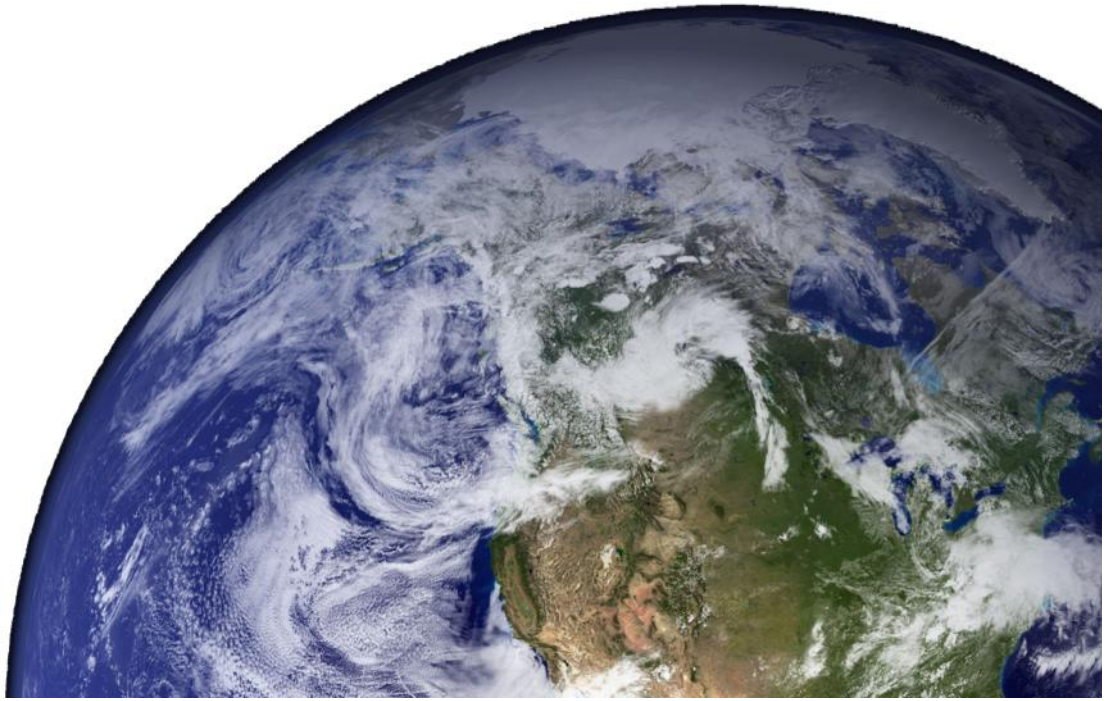
Harvest Data Collection System

Methodology



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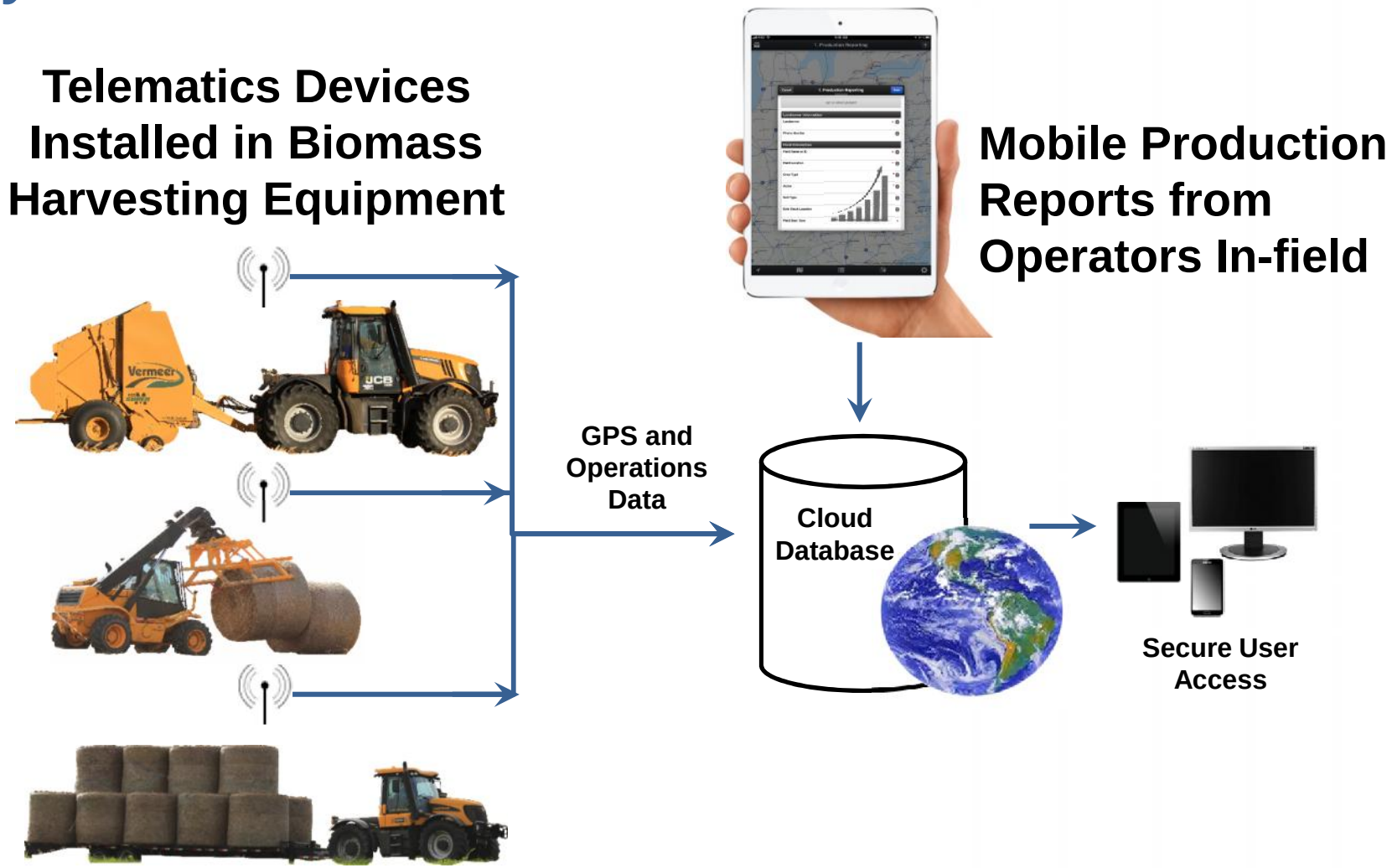
System Overview



System Details

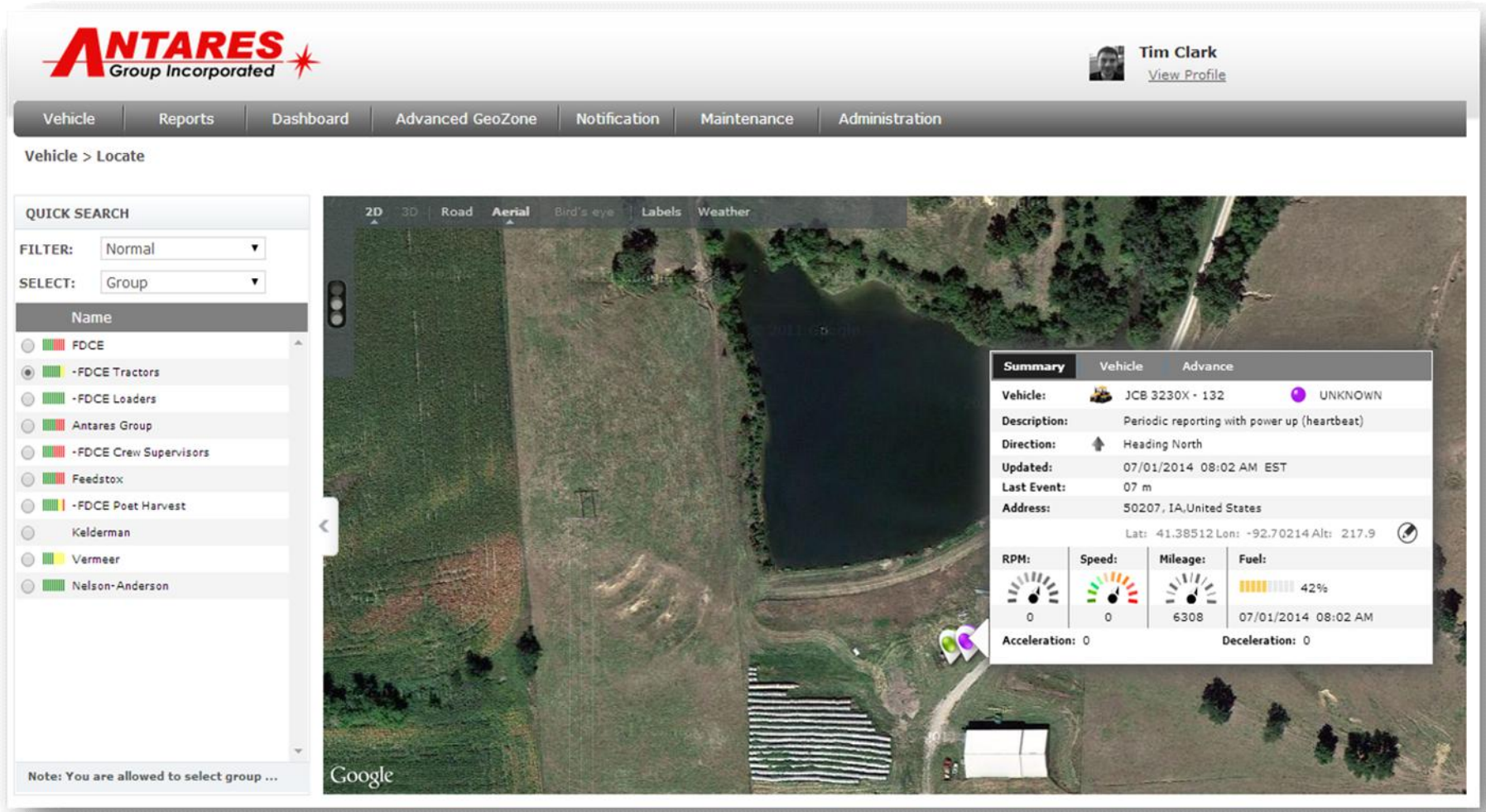
Telematics

- Automatically records:
  - Equipment ID
  - Location
  - Date/Time of Operations
  - Field Path
  - Engine Run Time (Engine Hours)
  - Engine RPMs
  - Speed

Mobile Production Reporting

- Allows operators to record:
  - Field ID
  - Equipment Used
  - Production Data
  - Biomass Quality
  - Maintenance Issues
  - Notes and comments
  - Photos of important items
    - Baler Monitor
    - Parts Replaced
    - Field Hazards

Live Tracking



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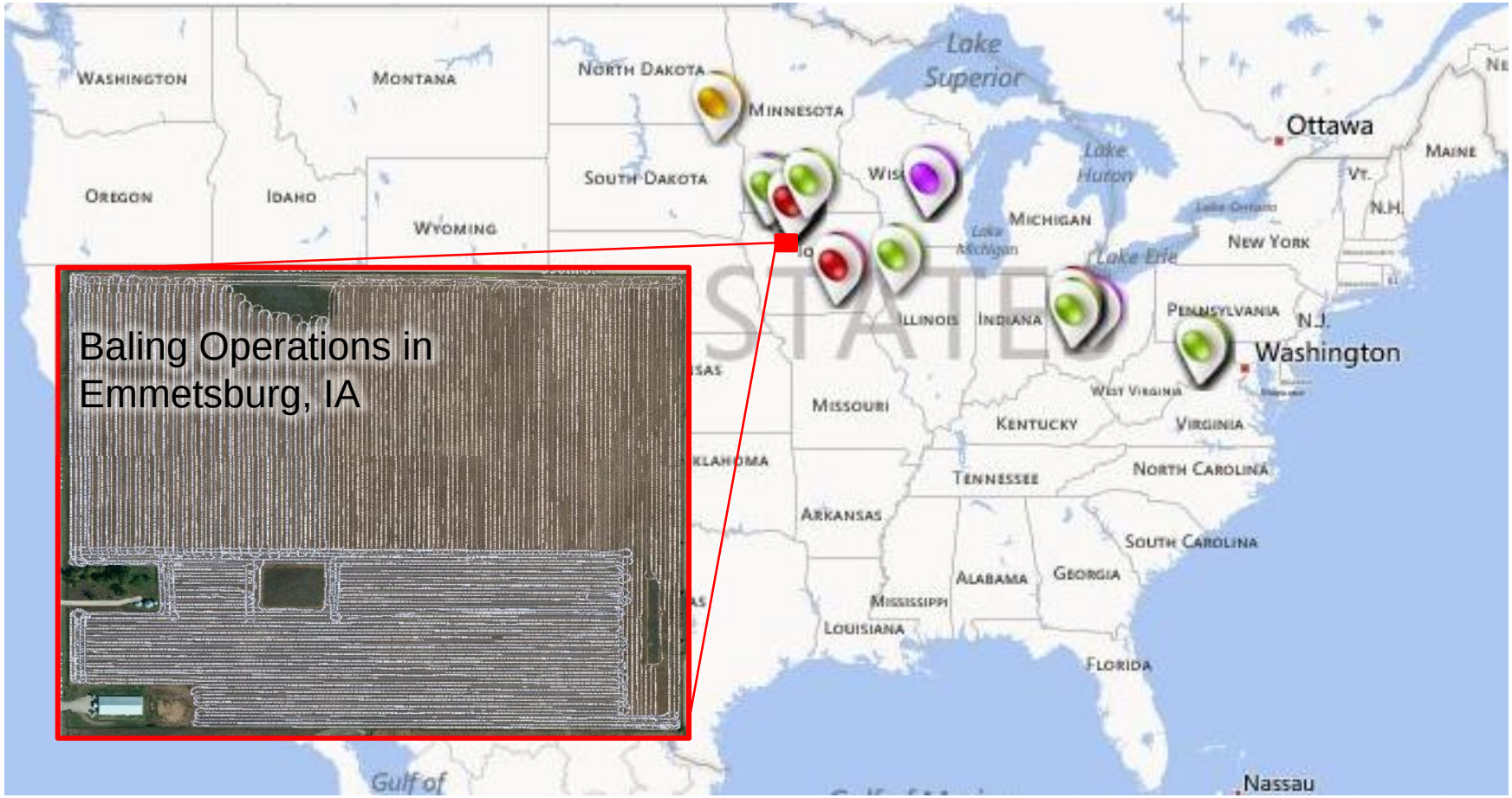

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Harvest Data Collection

- Operations Data
  - Tonnage Harvested
  - Biomass yield
  - Time in Field
  - Productivity
  - Biomass Quality
  - Equipment performance
- Cost Data
  - Equipment Costs
  - Labor Costs
  - Fuel Costs
  - Maintenance Costs
  - Indirect Costs
  - Other costs

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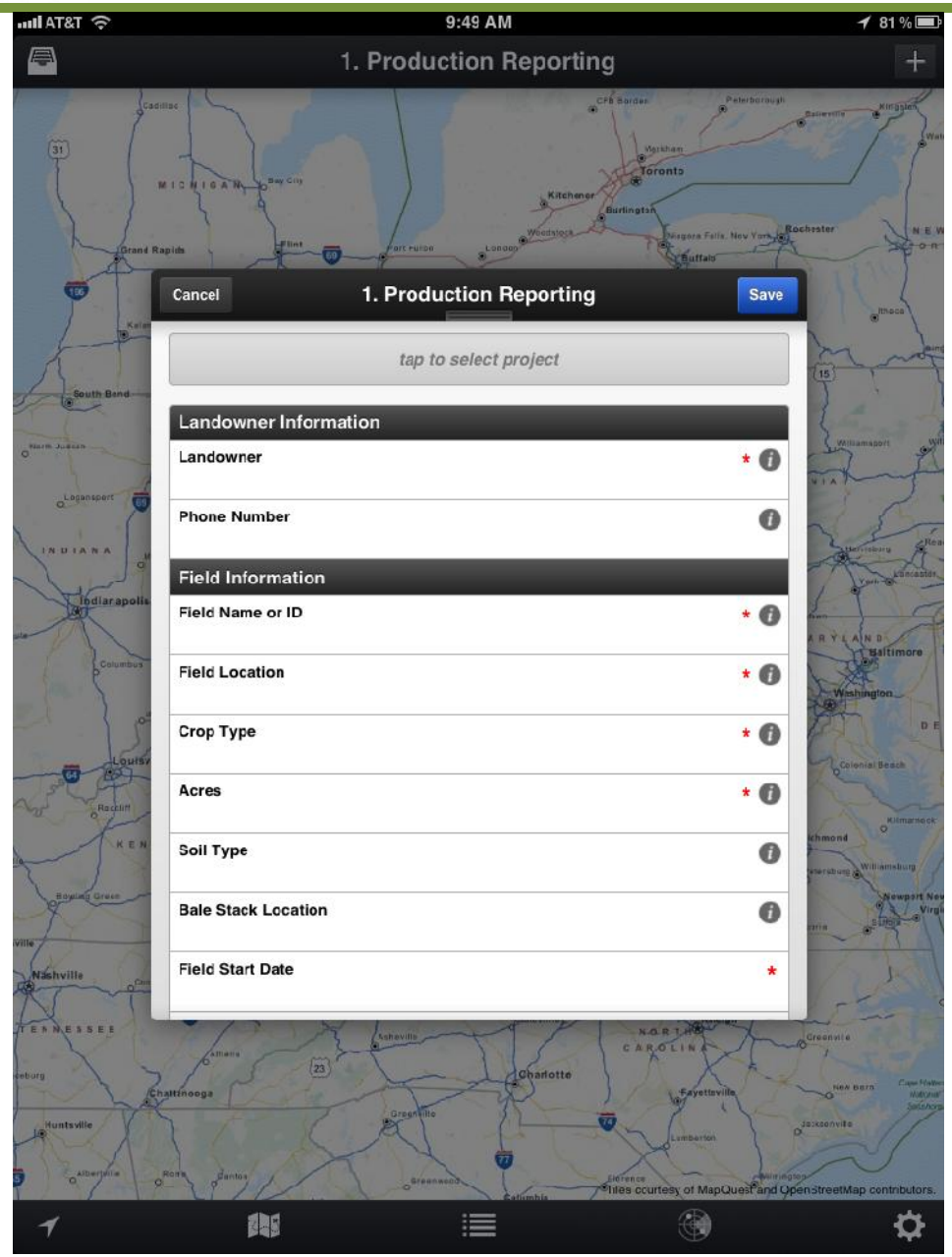
Mobile and Desktop Production Reporting



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Methodology

Start of Day/ Job Begins

- **Submits *Job Start Report***
  - Field ID
  - Equipment ID
  - Start Metrics

During field Operations

- **Submits *Maintenance Report***
  - Field ID
  - Equipment ID
  - Parts Replaced
  - Time Required

End of Day/ Job Complete

- **Submits *Job Completion Report***
  - Field Id
  - Equipment ID
  - End Metrics
  - Notable Issues and Comments

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Created	Updated	Created By	Updated By	Assigned	Project	Landowner/Field ID	Crew Leader	Operations Conducted
2013-10-21 20:32 -04:00	2013-10-30 19:52 -04:00	Equipment Operator	Equipment Operator			Iowa Corn Stover Harvest (POET) ▸ 350941	Kyle Mason	Loader
2013-10-21 16:08 -04:00	2013-10-29 19:23 -04:00	Equipment Operator	Equipment Operator			Iowa Corn Stover Harvest (POET) ▸ 350917	Kyle Mason	Loader
2013-10-22 19:52 -04:00	2013-10-22 19:52 -04:00	Equipment Operator	Equipment Operator			Iowa Corn Stover Harvest (POET) ▸ mikes field	Kyle Mason	Loader
2013-10-22 19:52 -04:00	2013-10-22 19:52 -04:00	Equipment Operator	Equipment Operator			Iowa Corn Stover Harvest (POET) ▸ mikes field	Kyle Mason	Loader, Bale Wagon (Roadsiding)
2013-10-21 20:30 -04:00	2013-10-22 17:22 -04:00	Equipment Operator	Equipment Operator			Iowa Corn Stover Harvest (POET) ▸ Mikes field	Kyle Mason	Baling
2013-10-21 20:28 -04:00	2013-10-22 17:20 -04:00	Equipment Operator	Equipment Operator			Iowa Corn Stover Harvest (POET) ▸ mikes field	Kyle Mason	Baling

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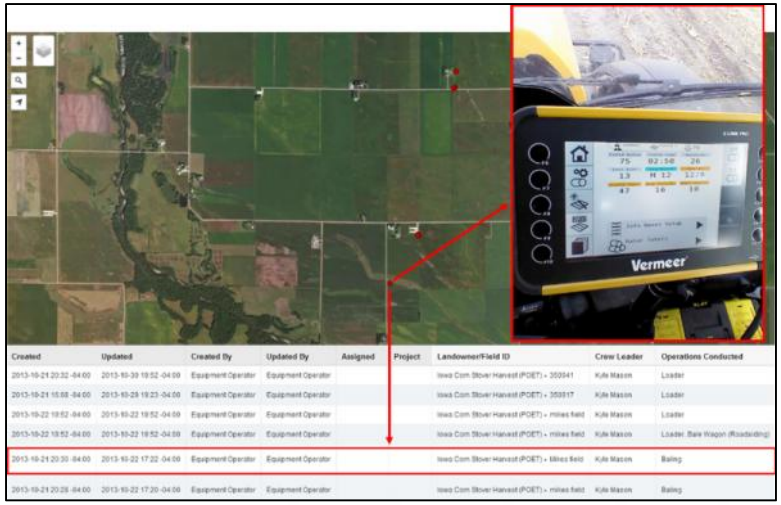

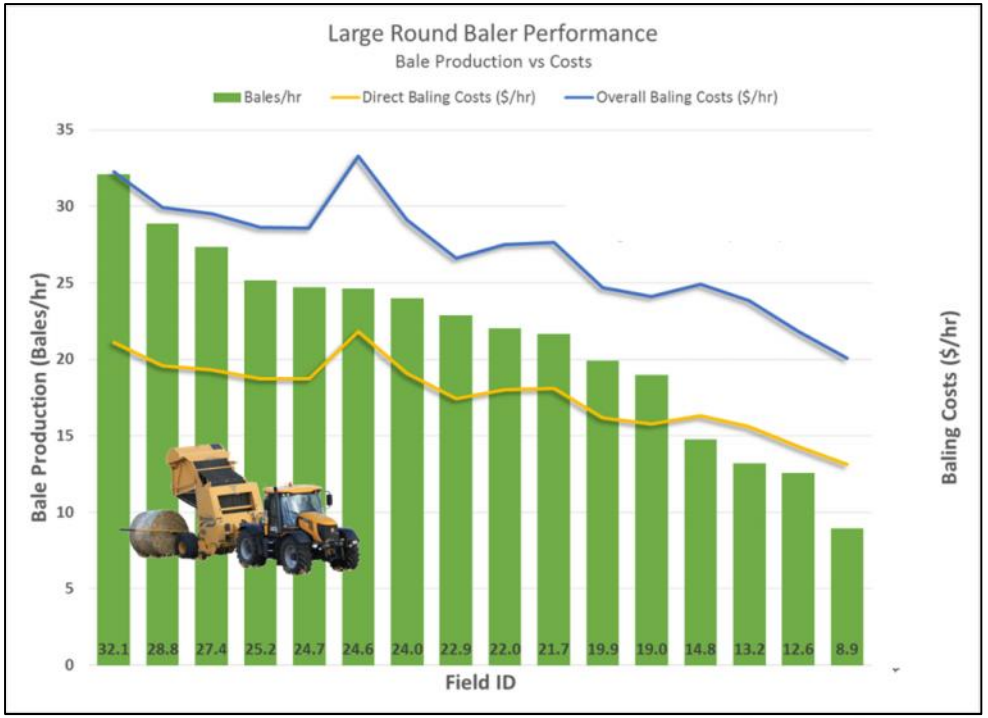

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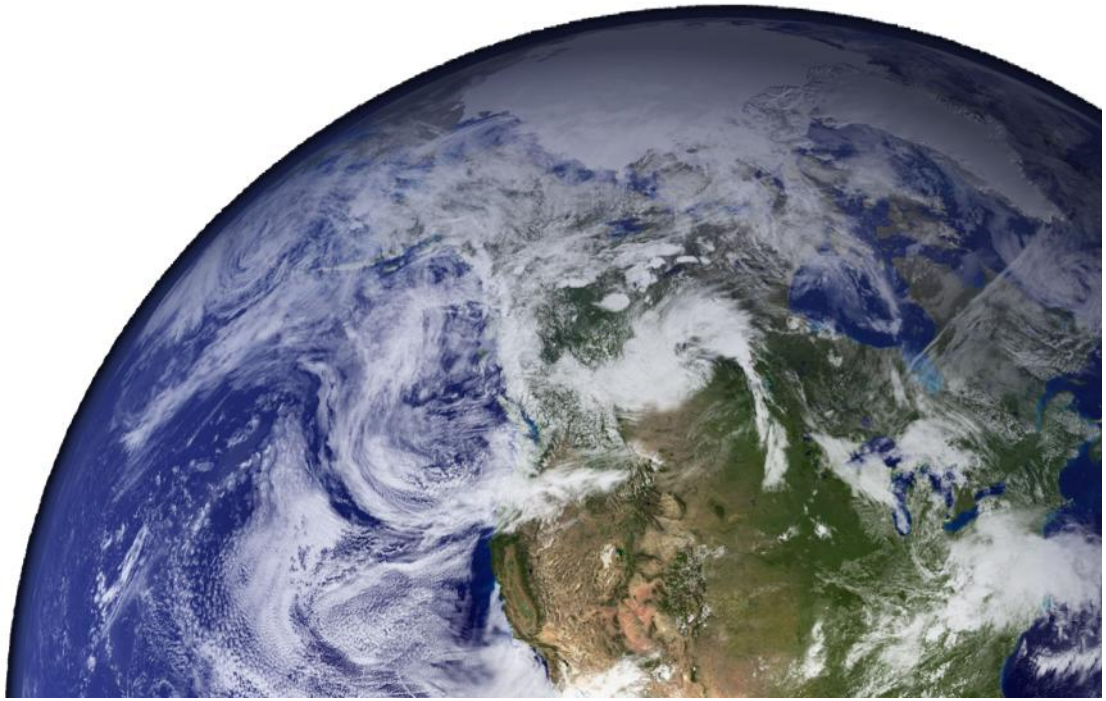
Harvest Data Collection System

Results



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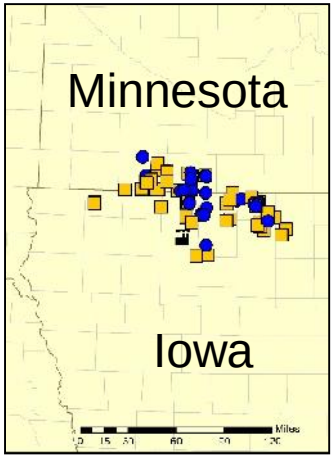
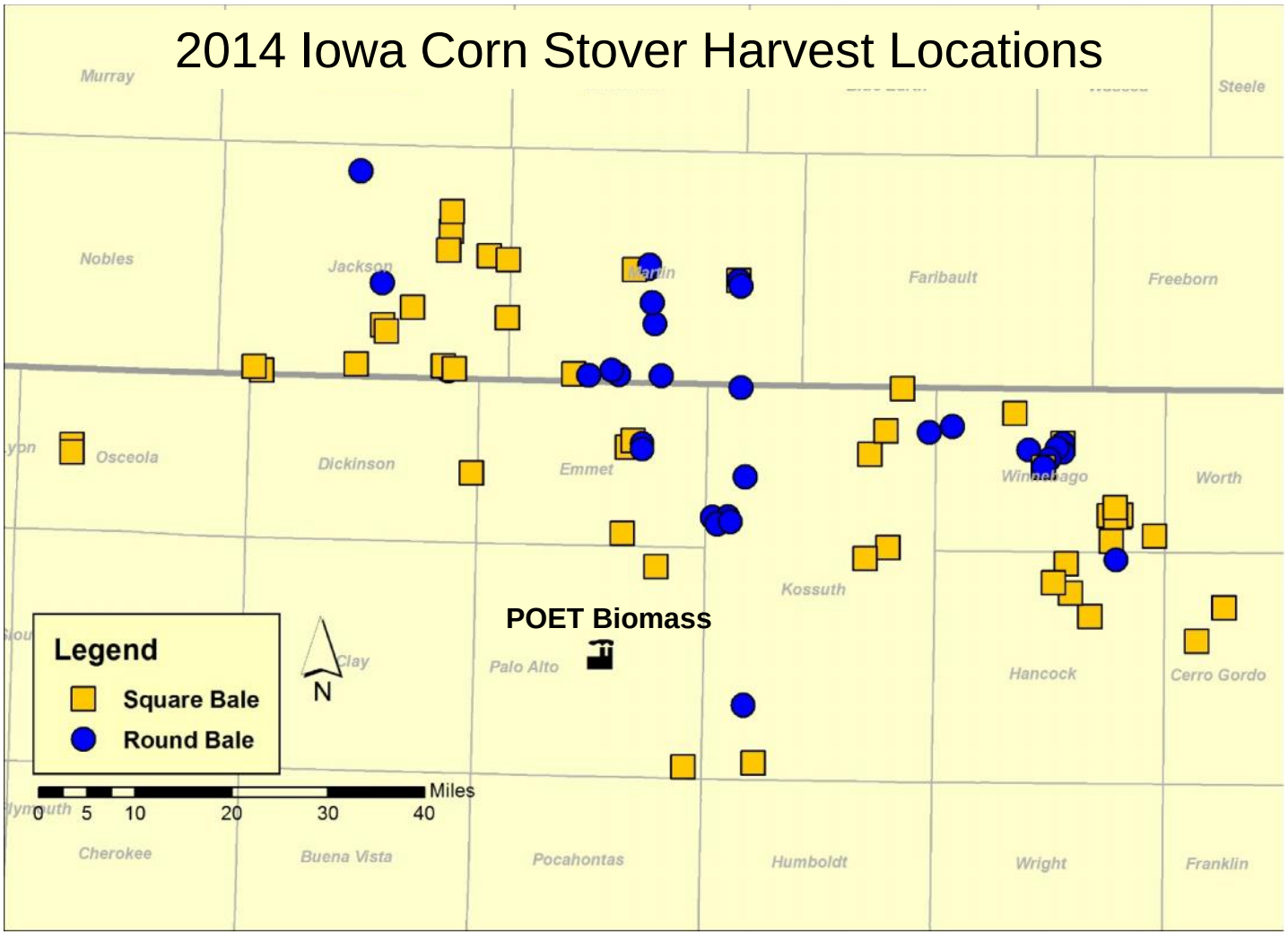
2014 Iowa Corn Stover Harvest Summary

- Followed "EZ Bale" Harvest Protocol – Square & Round Bales
  - 37,000 Acres
  - 53,492 Bales Harvested (31,175 dry tons @ 1,384 lbs/bale, avg.)
    - Round Bale Ave: 1,318 lb/bale; Square Bale Ave: 1,393 lb./bale
  - Ave. Moisture Content: 15%; Ave. Ash Content: 8.7%
  - Biomass Yield: 0.85 dry tons/acre

POET EZ Bale Protocol
Windrowing by combine only, no raking or shredding allowed.


Minnesota
Iowa


2014 Iowa Corn Stover Harvest Locations
Murray
Steele
Nobles
Jackson
Faribault
Freeborn
Osceola
Dickinson
Emmet
Worth
Kossuth
POET Biomass
Legend
Square Bale
Round Bale
N
Clay
Palo Alto
Hancock
Cerro Gordo
Miles
0 5 10 20 30 40
Cherokee
Buena Vista
Pocahontas
Humboldt
Wright
Franklin

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Example of Equipment Tracks: Baling Operations

Precision Monitoring System

Low-cost Monitoring System

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Example of Equipment Tracks: Stinger Stacker 6500 Roadsider

Two (2) Stinger Roadsiders were used to roadside bales in this field.

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Variables Impacting Harvest Performance & Costs

- Biomass Yield
- Harvesting equipment and settings
  - Combine
  - Rakes/shredders
  - Baler pickups
- Operator experience, skill, mindset, and training
- Harvesting process (rake vs. no-rake) – Customer specification
- Bale density, size, and format
- Moisture Content
- Weather (harvest window)
- Field size, condition (soft, wet, etc…), topography, obstacles, and orientation
- Crop condition (physical condition of the crop, e.g.: too moist or flattened)
- Orientation of bales in the field
- Ash Content

Variables Within Our Control

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Conventional Harvest Operation #1

Baling: 5'x6' Large Round Bales

Roadsiding: Collect and Load Bales onto Bale Wagon

Roadsiding: Transport Bales to In-field Storage

Roadsiding: Unload Bales into In-field Storage

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Conventional Harvest Operation #2

Baling: 5'x6' Large Round Bales

Roadsiding: Roadsider picks up bales in-field and carries them to in-field storage

Roadsiding: Unload Bales into In-field Storage

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Conventional Harvest Operation #3

Baling: 5’x6’ Large Round Bales

Roadsiding: Roadsider picks up bales in-field and carries them to in-field storage

Roadsiding: Unload Bales into In-field Storage

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JCB Tractors with Vermeer 605 SM Round Balers

Sample Field Tracks

- | 2013 | 2014 |
  - 21.4 bales/hr | 15.6 bales/hr
  - 19.9 acres/hr | 20.3 acres/hr
  - 12.3 BDT/hr | 9.0 BDT/hr
  - 7.5 gal/hr (fuel) | 7.2 gal/hr (fuel)
  - 1,135 lb/bale | 1,318 lb/bale
  - Moisture: 13.9% | 11.4%

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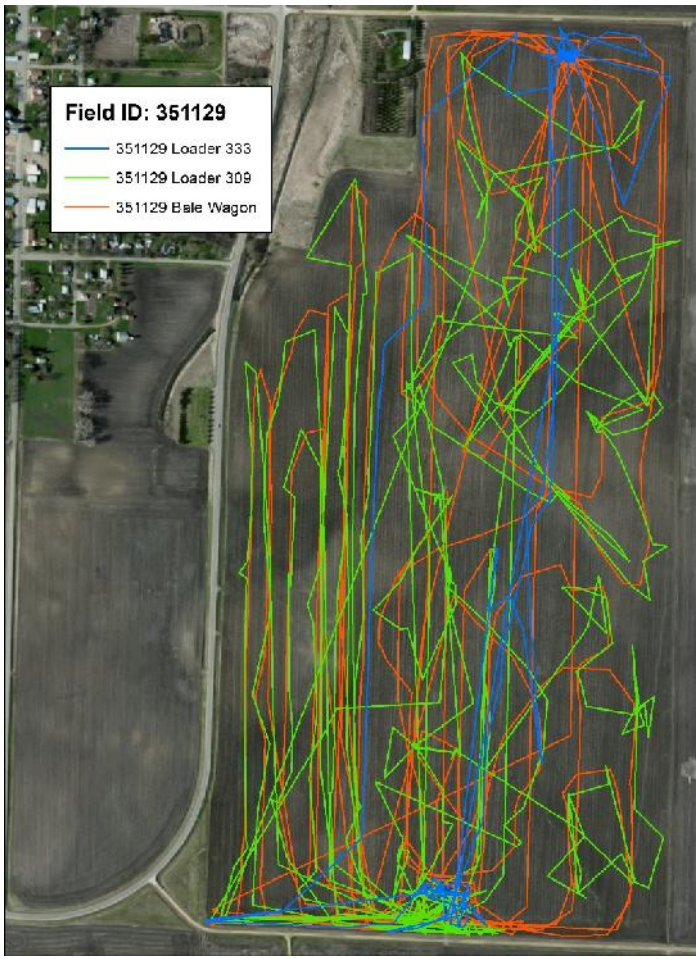
Two Telehandlers and JCB 3220 w/ Bale Wagon

Sample Field Tracks



- Data Summary from ~2,080 acres
  - 1.9 loads/hr @ 14 bales/load
  - 26.8 bales/hr
  - 20.8 acres/hr
  - 14.7 BDT/hr
    - Based on measured data from 2013 CS Harvest:
    - 1,135 lb/bale, average
    - 11.8% moisture content, average
  - ~173 miles traveled in-field (0.08 mi/ac)
- Notes:
  - Hourly results are based on the duration of bale moving operations in each field
  - Bale counts are based on actual bales made in each field, not the number times the bales were handled (in this operation, each bale is handled multiple times)
  - This operation includes 3 pieces of equipment with 3 separate operators

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Truck-mounted 12-bale Side Loading Bale Mover

Sample Field Tracks

Overall Summary of Operations with in-field staging areas

- Preliminary Data Analysis on ~1,415 acres
  - 5.1 loads/hr @ 12 bales/load
  - 60.6 bales/hr
  - 46.5 acres/hr
  - 30.2 BDT/hr
    - Based on measured data from 2013 CS Harvest:
    - 1,135 lb/bale
    - 11.8% moisture content
  - ~195 miles traveled in-field (0.13 mi/ac)

Notes:

- Hourly results are based on the duration of bale moving operations in each field
- Bale counts are estimated, based on average biomass yield and bale weight data collected from other harvests in the region during the same period

12-bale Pull-Type Side Loading Bale Mover

Sample Field Tracks

- 3.0 loads/hr @ 12 bales/load
- 35.4 bales/hr
- 23.4 BDT/hr
- 1,318 lb/bale
- 11.4% moisture content
- 4.7 gal/hr (fuel consumed)

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Conventional Large Square Baling Flow Diagram

Baling: 3’ x 4’ x 8’
Large Square Bales

Roadsiding: Collect and Transport Bales to In-field Storage

Roadsiding: Unload Bales at In-field Storage

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JCB Tractors with Challenger XD Square Balers

Sample Field Tracks

- 2014 Production Summary
  - 26.7 bales/hr
  - 15.8 BDT/hr
  - 7.8 gal/hr (fuel consumption)
  - 1,393 lb/bale
  - 15.7% moisture content

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Stinger Stacker 6500 Roadsider

Sample Field Tracks

Overall Summary of Operations with in-field staging areas

- 2014 Production Summary
  - 4.0 loads/hr @ 12 bales/load
  - 48.4 bales/hr
  - 30.2 BDT/hr

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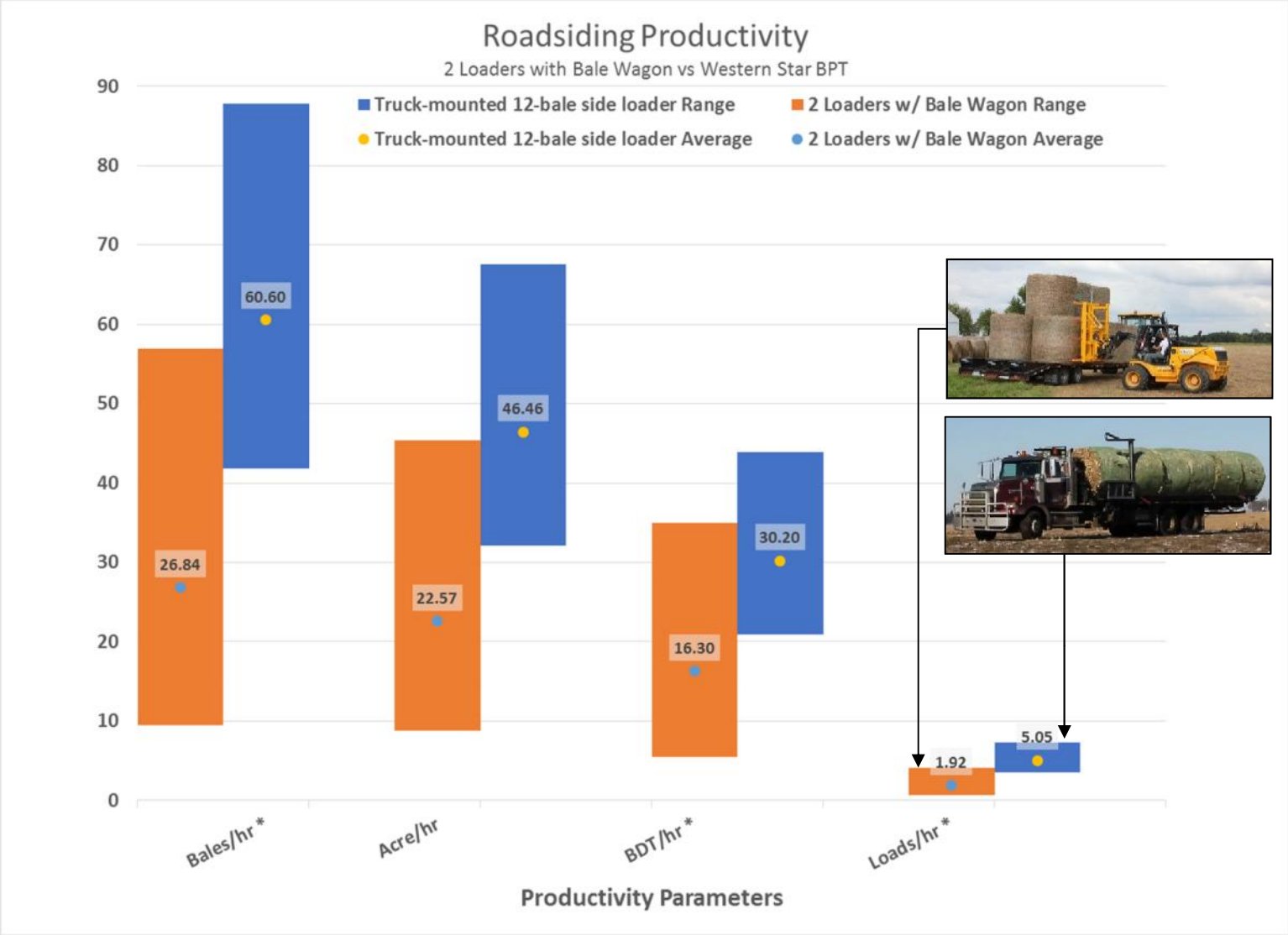
2013 Roadsiding Productivity Comparison



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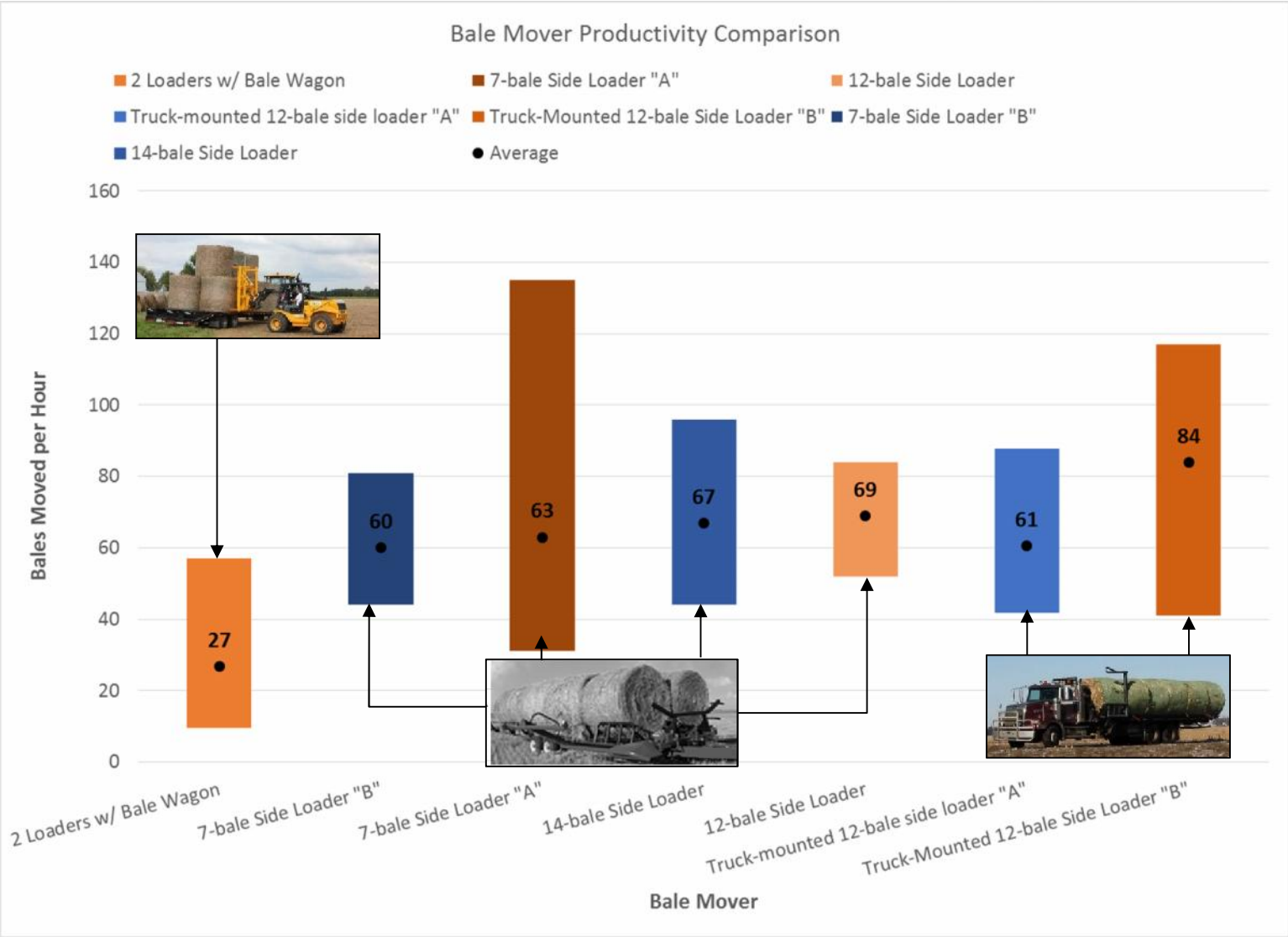
2013 Roadsiding Productivity Comparison



Results with Caveats

- Results are based on actual in-field reporting during operations by field operations staff and performance measured by Antares staff both remotely and in-person.
- Results do not factor in additional costs due to:
  - Equipment freight and crew transportation
  - Lodging and meals
  - Support staff and vehicles
  - Routine equipment maintenance
  - Equipment downtime due to malfunction or other stoppage
  - Supplies such as net wrap and wear-parts
- No windrowing was conducted during harvest
- Biomass yield (BDT/acre) is calculated from measured weight of material harvested divided by the total area of the field.
  - Biomass Yield = Harvested Bone Dry Tons ÷ Total Field Area

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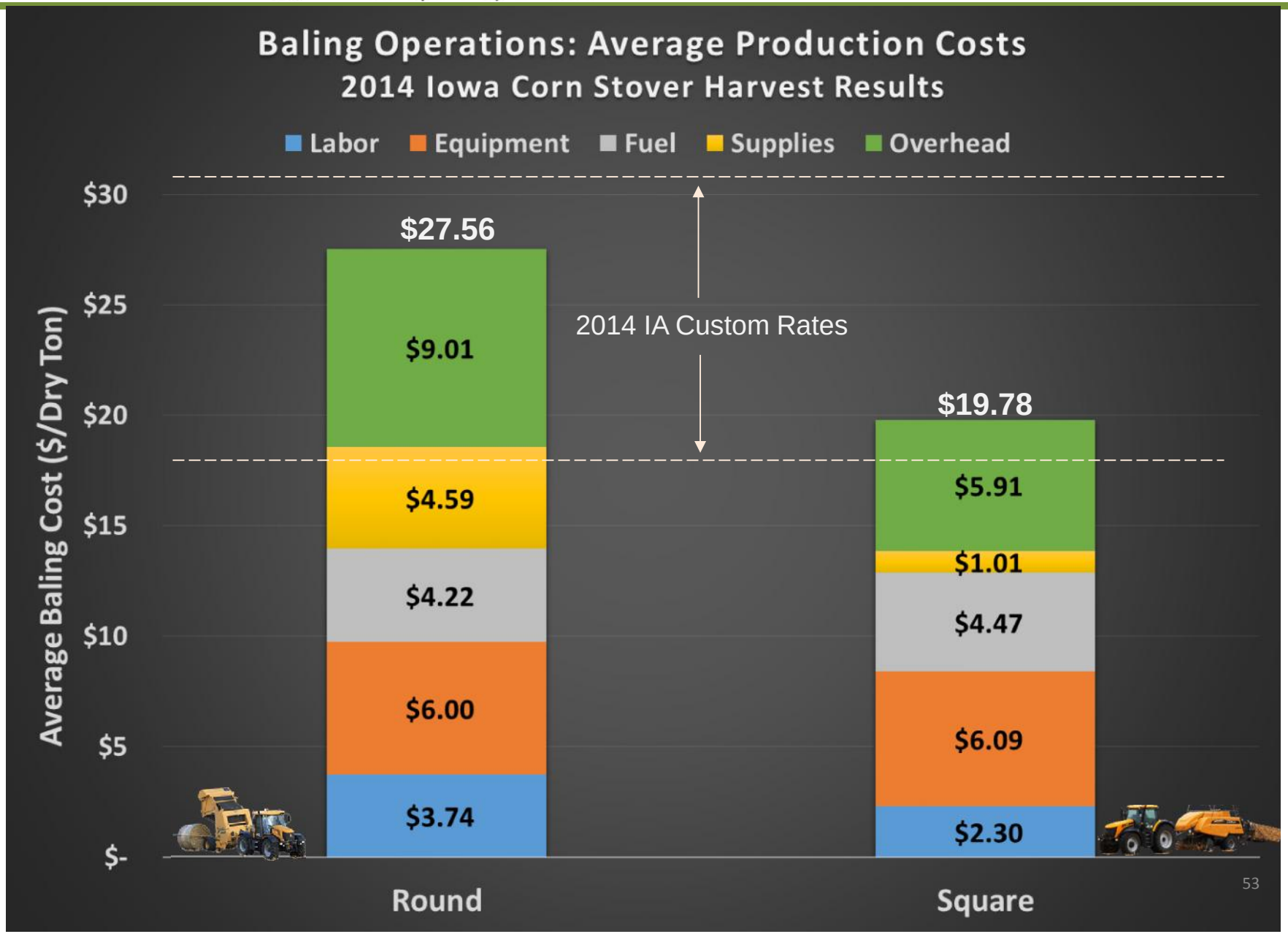

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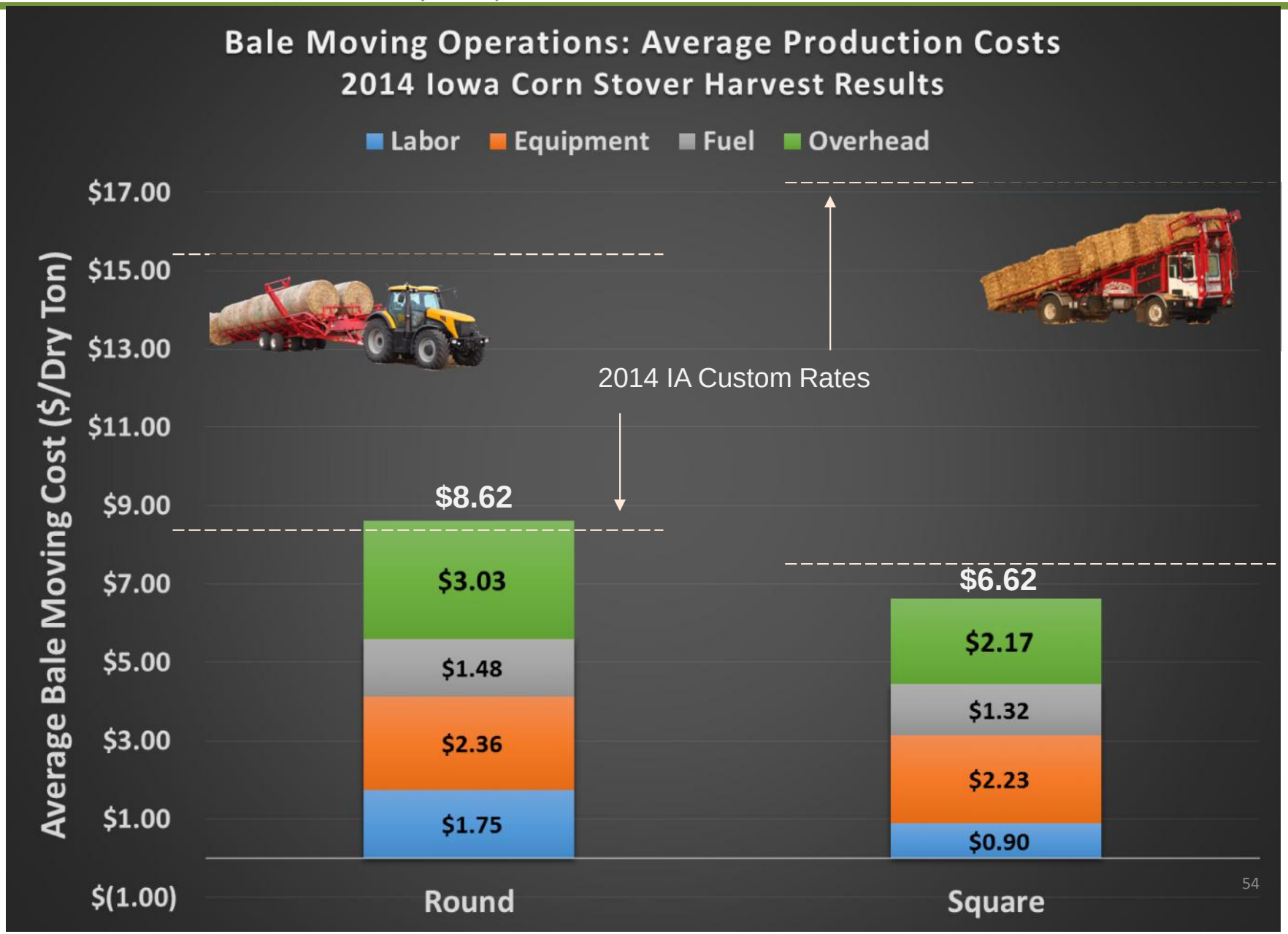

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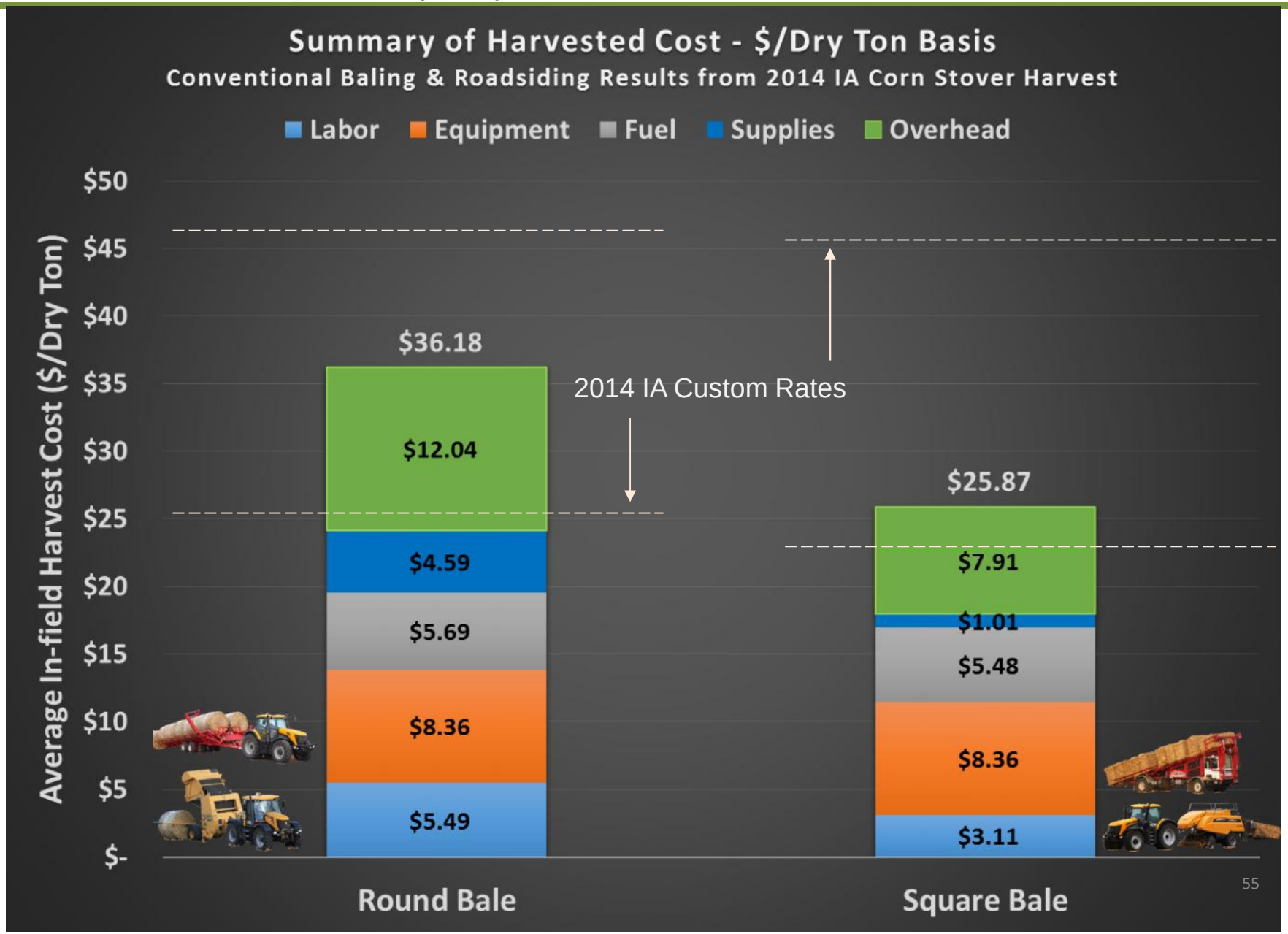

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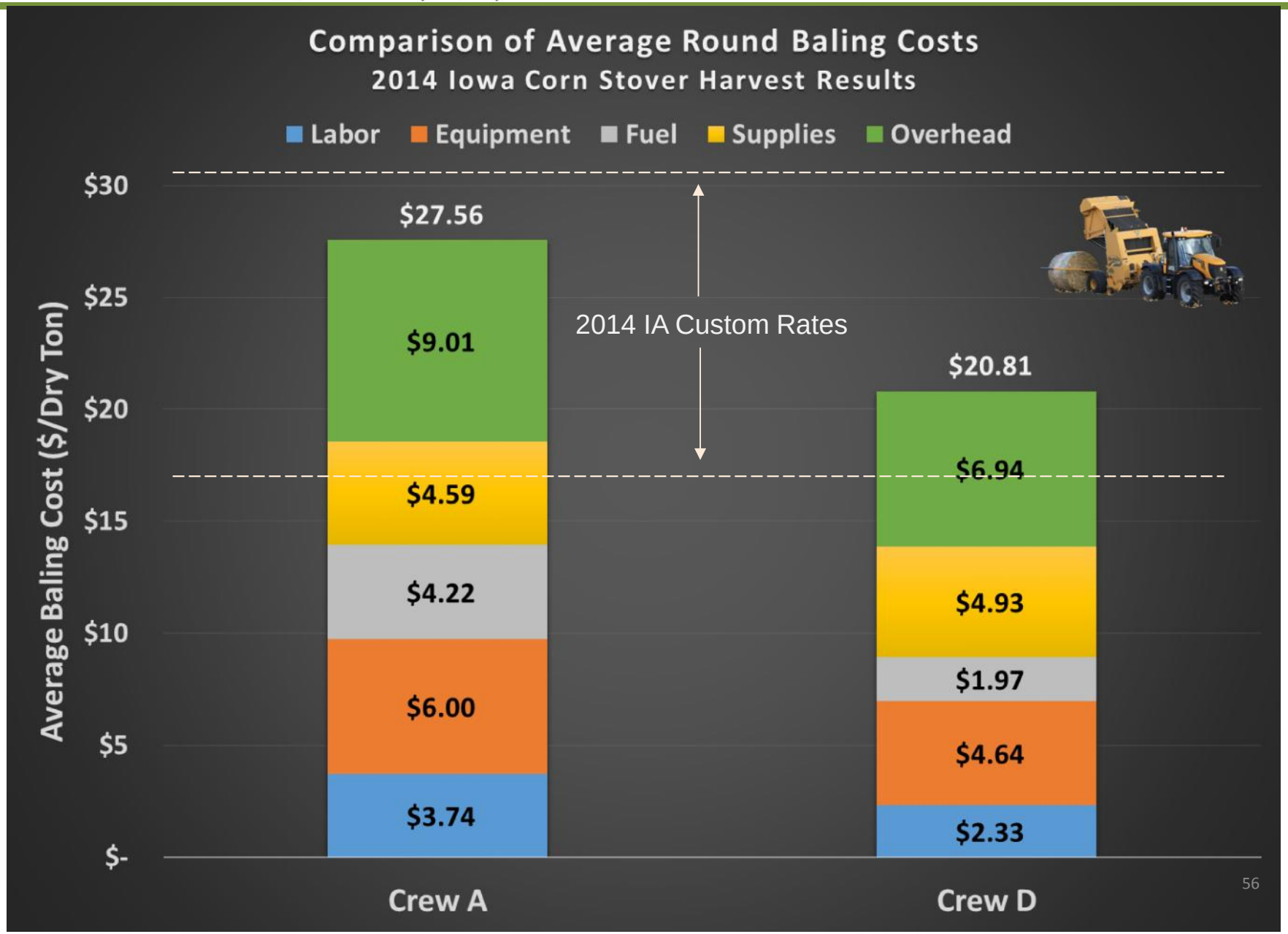

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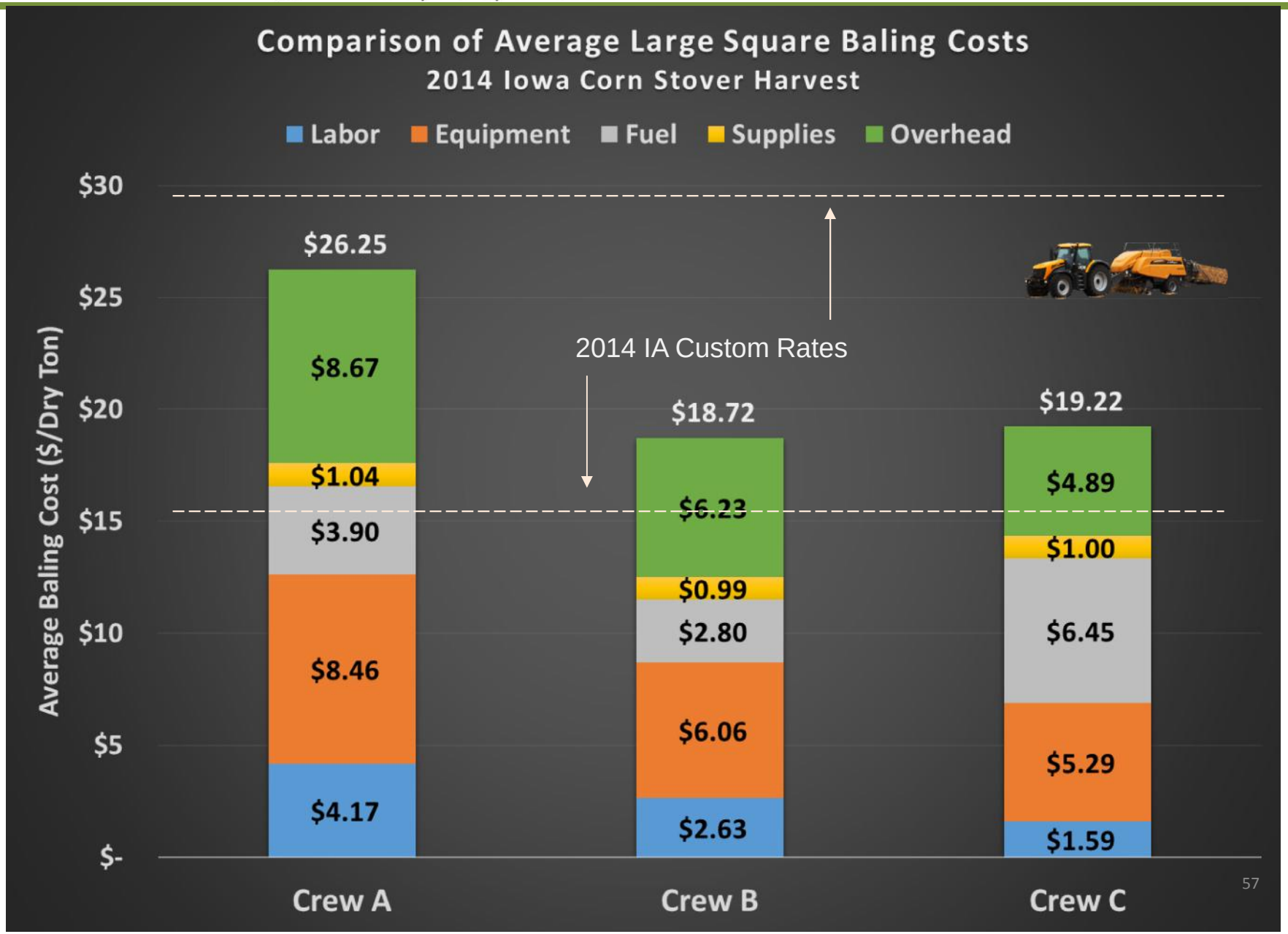

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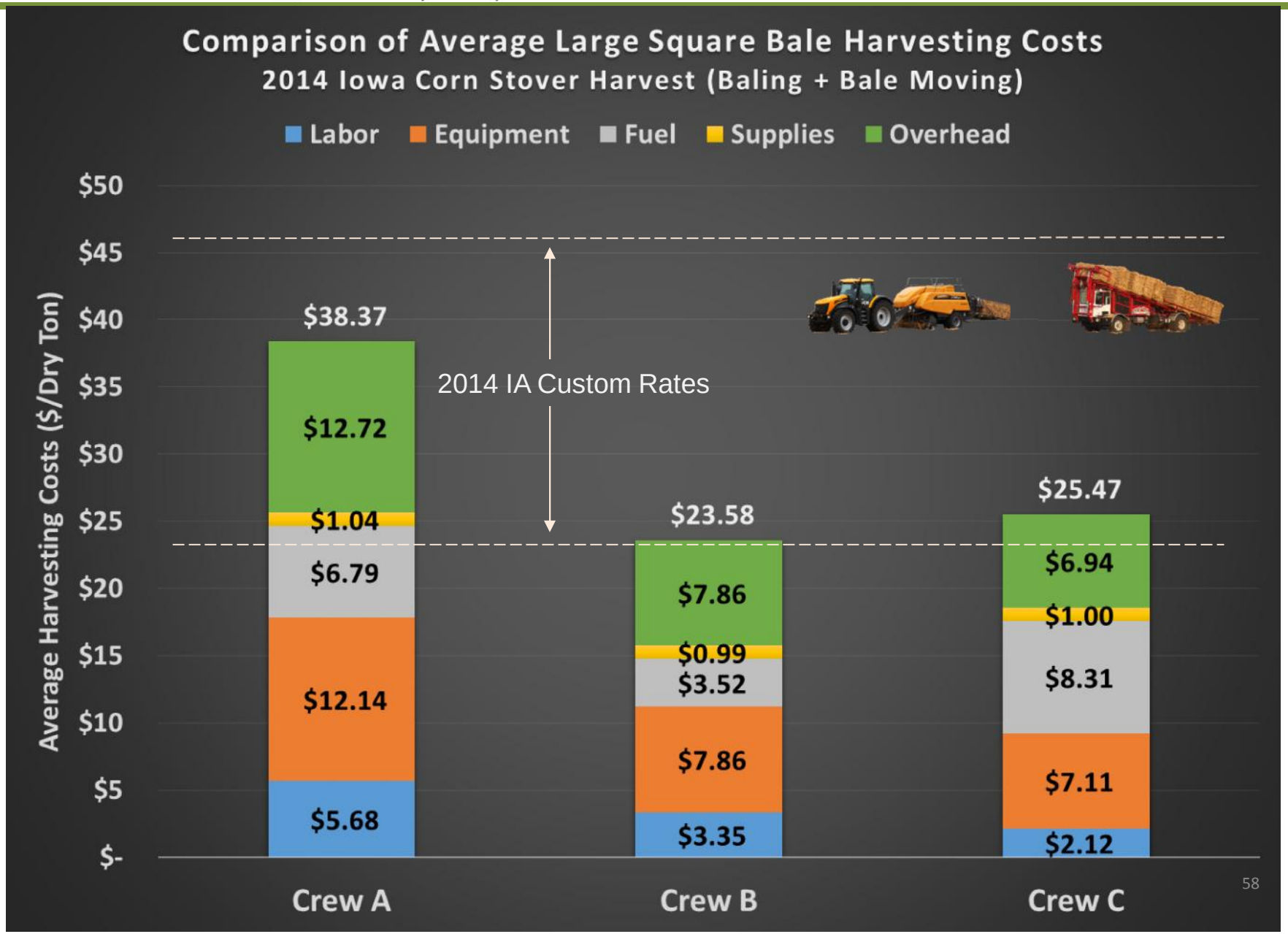

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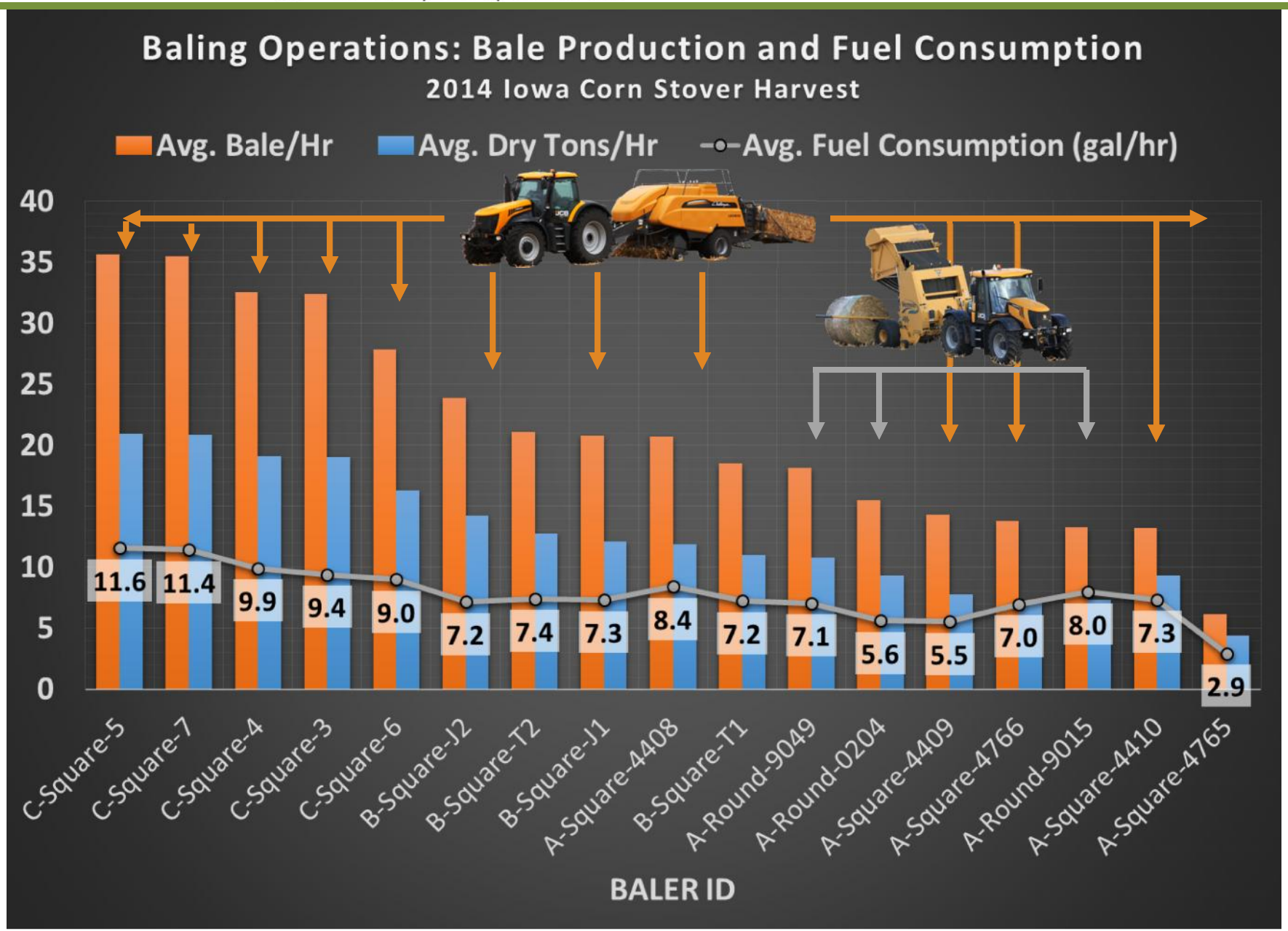

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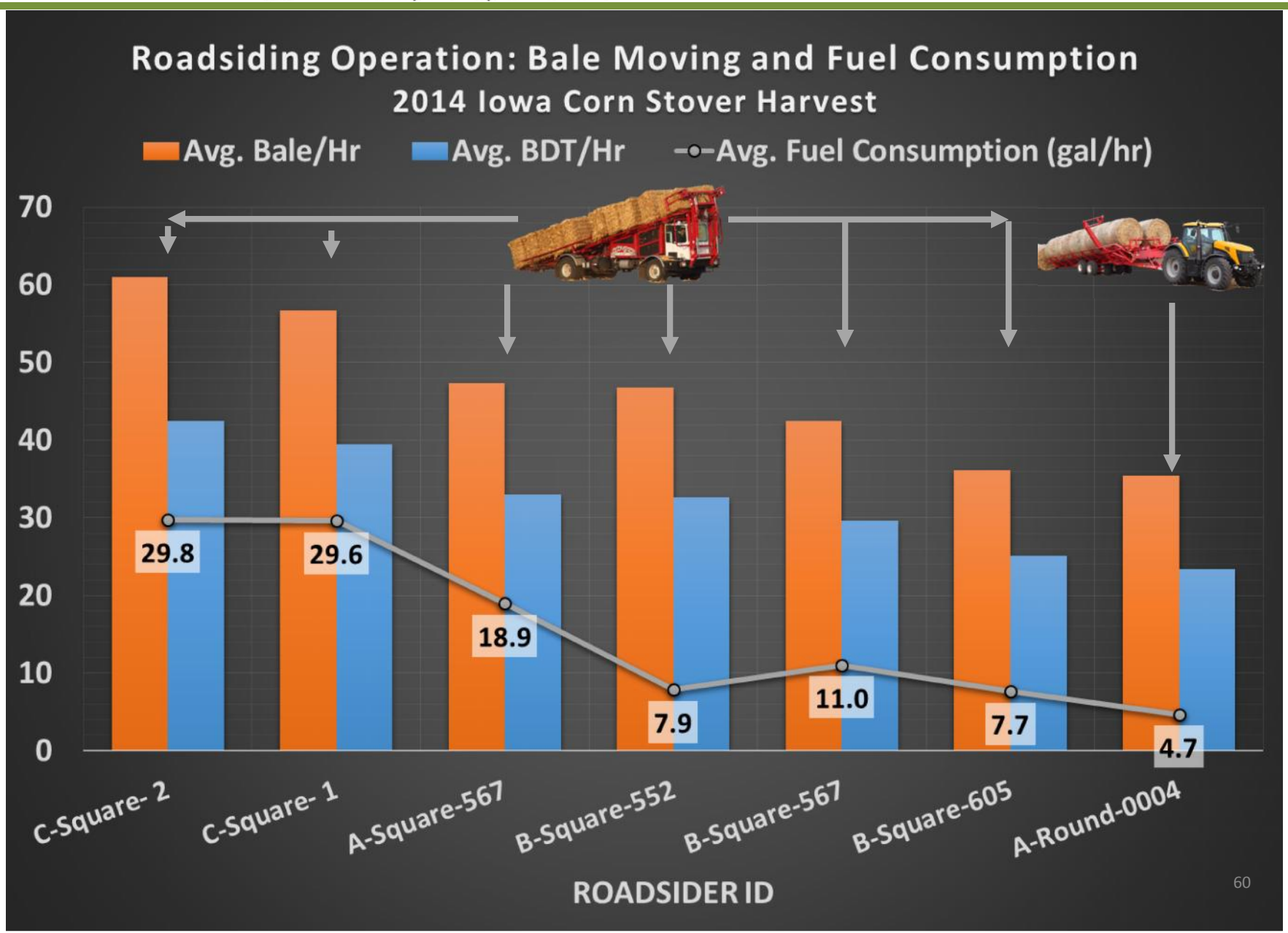

2014 EZ Bale Corn Stover Summary

- Biomass Yield: 0.85 BDT/Acre, Range: 0.41 – 1.91
- Moisture Content: 15.2%, Range: <7% – >30%
- Ash Content: 8.7%, Range: 4.2% – 14.9%
- Square Bale (3'x4'x8')
  - Weight: 1,393 lbs, Range: 1,024 -
  - Bulk Density: 14.8 lb/CF, Range: 10.7 – 18.6
- Round Bale (6'x5')
  - Weight:1,318 lbs, Range: 1,001 – 2,218
  - Bulk Density: 9.3 lbs/CF, Range: 7.6 – 10.8

Next Steps

1. Identify the impacts of operator experience on cost

2. Collect more data from Advanced Equipment

3. Collect detailed cost and performance data from transport operations

4. Continue to build the dataset with additional data