DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review

2015 “BALES” Project Review

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Technology Area Review

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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
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._
Quad Chart Overview

Timeline

- Project start date: 9/30/2013
- Project end date: 9/30/2016
- Percent complete: 45%

Barriers

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

Budget

<table>
<thead>
<tr>
<th></th>
<th>Total Costs FY 10 – FY 12</th>
<th>FY 13 Costs</th>
<th>FY 14 Costs</th>
<th>Total Planned Funding (FY 15-Project End Date)</th>
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Project Cost Share by Contributing Partner

- **Vermeer**
  - FY 14 Costs: $993,977
  - Total Planned Funding: $5,396,574
- **Kelderman Mfg.**
  - FY 14 Costs: $109,144
  - Total Planned Funding: $700,713
- **Other**
  - FY 14 Costs: $153,197
  - Total Planned Funding: $746,803
- **Poet Biomass**
  - FY 14 Costs: $53,989
  - Total Planned Funding: $646,011
- **Others (harvest collaborators)**
1 - Project Overview

- Project Background and Team History
Project #1: Design and Demonstration of a Comprehensive Biomass Feedstock Supply System
Biomass Alliance for Logistics Efficiency and Specifications

Project Overview

(Team History)

Seeking to replace this...

Mow / Windrow

Baling

Roadsidding

Bale Yard Storage

Recover Storage

Load Into Process Line

Unload to Storage

Transport

Load for Transport
With this...

**Single Pass Harvesting**
Freeman 1592D Self-Propelled
Removes one pass through the field

**Load Directly Onto Process Line**

**Transport**
Self Loading Trailer
Removes loading and unloading operations

**Roadsiding**
Bale Picking Truck
Reduces # trips in the field by 67%

**Bale Yard Storage**
Project Overview

(Team History)
Poet-DSM’s Project Liberty – Emmetsburg, IA
2 – Approach (Technical)

• Develop and Demonstrate New or Improved Biomass Harvesting and Processing Equipment
  – Designed equipment to fill gaps in the biomass supply chain (harvest and processing), for square and round bale systems
  – Continuous development cycle (Design → Build → Test → Improve)
  – Improved in-field harvest data collection systems to build a more robust set of cost and performance data

• Develop Rapid and Reliable Quality Assessment Tools
  – Collect biomass quality data (moisture, ash, carbohydrates) rapidly through in-field Near Infrared Spectroscopy and rapid analysis tools

• Critical Success Factors and Key Challenges
  – All prototype equipment and innovations fabricated and tested
  – Demonstrate feedstock cost reduction at the end users’ specifications
  – Cultural changes and investment required to implement a new “system”
New additions to allow full truck unloading, automated de-stacking

Already Demonstrated / Documented (Chariton Valley)
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
Bale-Picking Truck, Biomass Trailer, De-Stacker
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
2 – Management Approach

• Assembled a proven multi-disciplinary team, with complimentary capabilities to perform all required functions from initial conceptual design to delivery and processing of feedstocks at the end-user’s facility.

• Planned equipment development and testing schedule for 3 yr period.

• Used DOE budget and progress reporting system to track and report progress

Key Management Challenges:

• Coordinating the project activities of 18 companies across 9 project tasks.
3 – Technical Accomplishments/ Progress/Results

• Harvest/Logistics Equipment Development & Demonstration
  – Round Bale Harvest System Improvements
    • Advanced in-field Round Bale Removal – May not market
    • Advanced Round Bale Transportation – May not market
    • Reduced Ash Content
    • Increased Round Bale Density
    • Reduce baler downtime through design improvements

  – Harvest data (cost and performance) collection conducted and summarized for round and square bale operations
    • 76,441 bales harvested (43,192 dry tons)
    • ~51,000 acres
    • 4,278 engine hours
    • 23 pieces of harvesting equipment
3 – Technical Accomplishments/ Progress/Results (cont’d)
3 – Technical Accomplishments/ Progress/Results (cont’d)

Telematics Devices Installed in Biomass Harvesting Equipment

- GPS and Operations Data
- Cellular Network
- Cloud Database
- Mobile Production Reports from Operators In-field
- Secure User Access
3 – Technical Accomplishments/ Progress/Results (cont’d)

2014 Iowa Corn Stover Harvest Locations

Legend
- Square Bale
- Round Bale

POET Biomass

Minnesota
Iowa

Miles

0 5 10 20 30 40

N

POET Biomass
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.
Baling Operations: Average Production Costs
2014 Iowa Corn Stover Harvest Results

- Labor
- Equipment
- Fuel
- Supplies
- Overhead

2014 IA Custom Rates

Average Baling Cost ($/Dry Ton)

- Round
  - Labor: $3.74
  - Equipment: $4.59
  - Fuel: $4.22
  - Supplies: $6.00
  - Overhead: $9.01
  - Total: $27.56

- Square
  - Labor: $2.30
  - Equipment: $4.47
  - Fuel: $6.09
  - Supplies: $6.09
  - Overhead: $5.91
  - Total: $19.78
Bale Moving Operations: Average Production Costs
2014 Iowa Corn Stover Harvest Results

- **$17.00**
- **$15.00**
- **$13.00**
- **$11.00**
- **$9.00**
- **$7.00**
- **$5.00**
- **$3.00**
- **$1.00**
- **$(1.00)**

**Average Bale Moving Cost ($/Dry Ton)**

**Round**
- **$3.03**
- **$2.36**
- **$1.48**
- **$1.75**

**Square**
- **$2.17**
- **$2.23**
- **$1.32**
- **$0.90**

2014 IA Custom Rates
Summary of Harvested Cost - $/Dry Ton Basis
Conventional Baling & Roadsiding Results from 2014 IA Corn Stover Harvest

- Labor
- Equipment
- Fuel
- Supplies
- Overhead

2014 IA Custom Rates

Round Bale
- Labor: $4.59
- Equipment: $8.36
- Fuel: $5.49
- Supplies: $5.69
- Overhead: $12.04

Square Bale
- Labor: $7.91
- Equipment: $8.36
- Fuel: $5.48
- Supplies: $5.69
- Overhead: $3.11
Comparison of Average Round Baling Costs
2014 Iowa Corn Stover Harvest Results

2014 IA Custom Rates

Average Baling Cost ($/Dry Ton)

Crew A

Crew D

Labor
Equipment
Fuel
Supplies
Overhead

$30
$25
$20
$15
$10
$5
$-

$27.56
$9.01
$4.59
$4.22
$6.00
$3.74

$20.81
$6.94
$4.93
$1.97
$4.64
$2.33
Comparison of Average Large Square Baling Costs
2014 Iowa Corn Stover Harvest

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<th>Fuel</th>
<th>Supplies</th>
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2014 IA Custom Rates
Comparison of Average Large Square Bale Harvesting Costs
2014 Iowa Corn Stover Harvest (Baling + Bale Moving)

2014 IA Custom Rates

<table>
<thead>
<tr>
<th>Crew</th>
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<th>Equipment</th>
<th>Fuel</th>
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<td>$7.86</td>
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<tr>
<td>C</td>
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<td>$8.31</td>
<td>$1.00</td>
<td>$25.47</td>
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Baling Operations: Bale Production and Fuel Consumption
2014 Iowa Corn Stover Harvest

- Avg. Bale/HR
- Avg. Dry Tons/HR
- Avg. Fuel Consumption (gal/hr)

BALER ID

C-Square-5
C-Square-7
C-Square-4
C-Square-3
C-Square-6
B-Square-J2
B-Square-T2
A-Square-4408
B-Square-J1
A-Round-9049
A-Round-0204
A-Square-4766
A-Round-9015
A-Square-4410
A-Square-4765

11.6
11.4
9.9
9.4
9.0
7.2
7.4
7.3
8.4
7.2
7.1
5.6
5.5
7.0
8.0
7.3
2.9
Roadsiding Operation: Bale Moving and Fuel Consumption
2014 Iowa Corn Stover Harvest

- Avg. Bale/Hr
- Avg. BDT/Hr
- Avg. Fuel Consumption (gal/hr)

ROADSIDER ID

C-Square-2: 29.8
C-Square-1: 29.6
A-Square-567: 18.9
B-Square-552: 7.9
B-Square-567: 11.0
B-Square-605: 7.7
A-Round-0004: 4.7
2015 Harvest Plans - Vermeer

- Explore variables in ash content. Some preliminary tests in 2014 would reduce the impact of baler pickup height settings as top reason for high ash content.

- Bale density – reduce bale quantity, storage impact, machine maintenance impact, moisture content impact.

- Operator experience – limited research in 2014 lead us to believe experienced operators can substantially reduce harvest cost (bales/hour, baler uptime, reduced maintenance). Once identified, how can we assist new operators to reduce the learning curve?
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:
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
• Over 2100 spectra collected and analyzed
• 2 – 4 core samples collected per bale
• Scans at 1” increments from surface to center in hole
• Scans at 4 directions (Up, Right, Down, Left)
• QC sample scanned at set intervals
• Much higher variability seen in aged bales
  • May require more extensive sampling for accurate assessment

NIR Standard and control chart
Updated Sampling Protocol:

- Scan at only 2 directions
- Calculate and report dry weight (DW) for glucan and ash
  - Avg. Glu. DW: New 40.3%, stored 40.0%
  - Avg. Ash DW: New 6.8%, Stored 7.6%
- 30 reading per core
- Sampling time 5-10 min. per hole

Future Plans:

- Expand and improve calibration
- Storage study with DAM project
4 – Relevance

• The project’s objectives align with the BETO’s goals to provide biomass feedstocks at or below $80/DT.
  – The biomass harvesting and processing equipment being developed and demonstrated under this project has demonstrated potential to help reach this goal.

• Developing rapid analysis tools and methods to enable more-efficient and lower-cost feedstock quality assessment throughout the supply chain.
  – This aligns with BETO’s goals for “Terrestrial Feedstocks” (found in Biomass Program Multi-Year Program Plan)
5 – Future Work

• Continued development and refinement of the NIR spectroscopy tools for rapid biomass analysis
• Development and Testing of new harvest and processing innovations
• Ongoing harvest demonstration and data collection activities
• Plan for 2015 fall agricultural residue harvests
• Process testing to meet biorefinery specs. (Summer, 2016)
• Continued team collaboration on sustainability issues.

• Upcoming key milestones:
  – Dual Drive Destringers and Automatic Destringer for Large Square Bales: Equipment Fabricated, Installed and Ready for Testing
1. **Approach**: 
   – Broad approach for developing system and operation innovations for round and square bale based systems.

2. **Accomplishments**: 
   – Initial prototypes developed for round and square bale systems 
   – Demonstrated initial capability of NIR probe for rapid biomass quality analysis, improvements ongoing 
   – Significant equipment performance and biomass quality data collection

3. **Relevance**: 
   – Significant cost reductions and reliability improvements are needed in feedstock delivery and processing systems—primary focus of this project.

4. **Success Factors and Challenges**: 
   – Getting all prototype equipment and innovations fabricated and tested 
   – Demonstrate feedstock cost reduction at the end users’ specifications 
   – Cultural changes and investment required to implement a new “system”

5. **Future Work**: 
   – Process equipment fabrication & demonstration 
   – Ongoing harvest demonstration and data collection activities, including innovations 
   – Kelderman Pre-loader and Destacker 
   – Continued development and demonstration of NIR bale probe 
   – Continued collaboration and progress on sustainability issues
Additional Slides
## Labor Rates

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<tr>
<th>Job Title</th>
<th>Hourly Rate</th>
<th>Billability</th>
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<tr>
<td>Operator</td>
<td>$13.85</td>
<td>100%</td>
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<td>Crew Leader</td>
<td>$29.06</td>
<td>30.0%</td>
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<td>Operations Manager</td>
<td>$45.00</td>
<td>7.2%</td>
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## Overhead Expenses

| Overall Indirect Rate | 50.0%       |

## Other Direct Costs

| Baling - Net Wrap ($/bale) | $0.035 | $/L.F. @ 4 wrap(s) | 18.85 L.F./bale |
| Baling - Twine ($/bale)    | $0.004 | $/L.F. @ 1 wrap(s) | 130 L.F./bale   |
| Grease - Square Bale ($/bale) | $0.008 | based on $4.00 /tube per 500 bales |
| Grease - Round Bale ($/bale) | $0.005 | based on $4.00 /tube per 800 bales |
| Diesel Fuel ($/gallon)     | $3.60   |

## Equipment Costs

| Large Square Baler (3x4x8)     | $2.07   | $/bale |
| Large Round Baler (5x6)        | $1.16   | $/bale |
| Small Round Baler (4x5)        | $1.16   | $/bale |
| Tractor Rental Rate ($/hp-hr)  | $0.12   | $27.44 |
| Stinger Stacker 6500           | $2.09   | $/bale |
| Loader                         | $18.75  | $/hr   |
| Pull-type round bale mover     | $1.40   | $/bale |