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2013 DOE BETO Project Peer Review

Integration of Advanced Logistical Systems and Focused Bioenergy Harvesting Technologies to Supply Crop Residues and Energy Crops in a Densified Large Square Bale Format

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May 20, 2013
Feedstock Supply & Logistics

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Principal Investigator

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

Project Objectives

- Demonstrate a comprehensive biomass supply system and determine representative costs associated with the system.

- Collect and deliver biomass of varied moisture and composition and observe effects on storage and biomass quality.

Large Square Baler

- Quantify mechanical, biological, logistic, and economic processes associated with systems.

- Achieve reliability growth of processes to ensure full scale operation of all system components at conclusion.

- Develop equipment set to a commercially ready status.

Quad Chart Overview

TIMELINE

Project Start Date:	2009 Fall Harvest
Project End Date:	Dormant Season Harvest 2011/Dec 2012
Percent Complete:	96% Complete—Final Report to be completed

PARTNERS

Project Management	AGCO
Transportation	Stinger Inc.
Data Acquisition and Analysis	INL, ISU, OSU, TAMU
Producers	Farmers, OSU, TAMU, Noble Foundation
Conversion Facilities	POET, Abengoa, Terrabon

BUDGET

Total Project Funding:	$11,740,482
DOE Share	$5,000,000
AGCO & Subs Share	$6,740,482
Funding for FY10:	$230,366
Funding for FY11:	$1,367,490
Funding for FY12:	0
Funding for FY13:	0
Average Annual Funding:	$798,928

BARRIERS ADDRESSED

- Low ash harvesting methods
- Harvest of high volume energy crops--cut, dry, and package
- Crop residue harvest methods capable of economically feasible harvest rates
- High speed handling and transportation

Project Overview

History

The low energy density of biomass materials necessitates labor efficient, high volume harvest and transportation systems.

- Densification and reliable & efficient logistics are key elements. The densified Large Square Bale represents the best currently accepted and utilized method. (11.75 lb/cu ft target = 44k lb load)
- Some biomass crops must be harvested wet and either dried or transported wet creating additional challenges.
- Degradation and loss during storage is a function of storage practice, material, time in storage, and moisture content.

Stored Switch grass @ Roadside 6 mo.

Corn Residue @ Roadside 1 wk.

Project Overview

Context

Utilize & adapt technologies where required for rapid adoption & modest capital requirements

- Equipment compatible with local infrastructures
- Equipment compatible with labor force and agronomic practices

Adapted

Existing

Project Overview

Objectives

Demonstrate and commercialize a production scale biomass collection system utilizing, where possible, a common set of equipment to minimize production costs.

- Energy Crops: energy sorghum, grasses, miscanthus
- Crop Residues: corn stover and wheat straw
- Determine Storage Characteristics
- Determine effect of moisture content on storage characteristics and best storage practices
- Validate sustainable harvest rates

Project Overview

Crops and Locations

- **Corn**

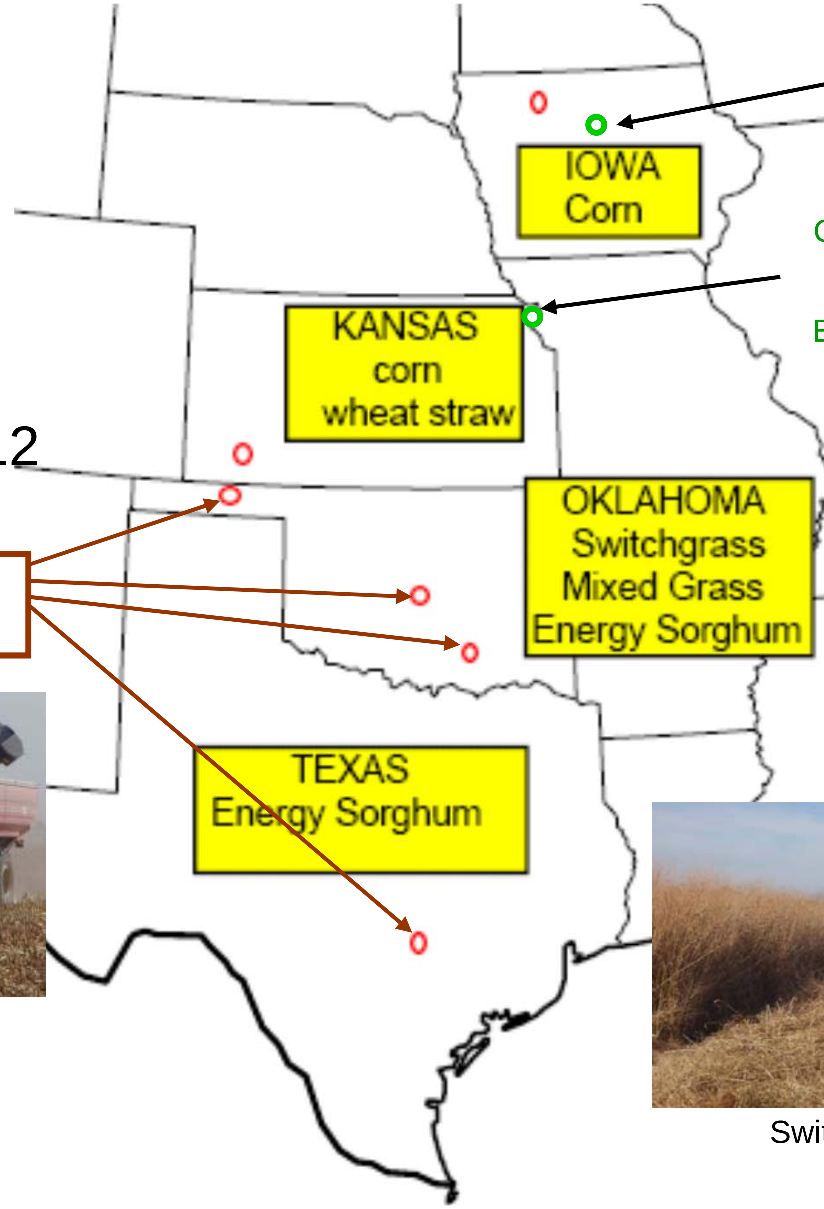
  2009, 2010, 2011

- **Wheat**

  2010, 2011

- **Energy Crops**

  2009, 2010, 2011, 2012



Single Pass Corn Residue

Switch grass

1 - Approach

- **Technical Approach**
  - Use state of the art/leading edge accepted harvest and transportation systems
  - Identify & Modify Systems as required to optimize performance
  - Validate modifications and move toward commercialization
- **Management Plan and Progress Milestones**
  - Plan based on growing seasons and weather variability, aligning with producer's plans
  - First Season (2009) Validate equipment function
  - Second Season (2010) Refine equipment and collect initial data
  - Third Season (2011)
    - Validate equipment reliability and collect data
    - Summarize data, assess costs, and sustainability
    - Re-visit DOT Road Safety Assessment
    - Re-assess customer (Producer & Refiner) Requirements
  - Fourth Season (2012)
    - Energy crop alternative sites due to drought

1 - Approach


Single Pass Wheat Harvest


Two Pass Energy Sorghum Cutting


Single Pass Corn Harvest


Two Pass Wheat Residue Baling

1 - Approach

Field Collection

Roadside Stacking

Storage

High Speed Loading

2-Technical Accomplishments/Progress/Results

- **Progress**
  - Harvesting and logistics systems have been validated
  - System improvements have been identified and implemented
  - Data acquired on typical field scenarios
- **Technical Objectives Achieved**
  - Developed understanding of requirements for good integrity of biomass bales
  - Quantified changes to machinery required for rapid adoption and economical harvest rates
  - Demonstrated harvesting methods minimizing ash
- **Key Milestones**
  - Single pass crop residue harvesting equipment has been validated on a commercial scale
  - Two pass systems have been validated on high volume energy crops
  - Corn head design improvements necessary to increase stover harvest rate from that of current designs (less than 1 t/ac) to levels above 2 t/ac were demonstrated, enabling significant corn stover feedstock cost reductions
  - Storage studies conducted on 3 crops
  - Logistic systems have been validated

2-Technical Accomplishments/Progress/Results

Single Pass Corn Harvest

Field Collection

Special purpose trailers 48 Bales (54,144 lbs.)

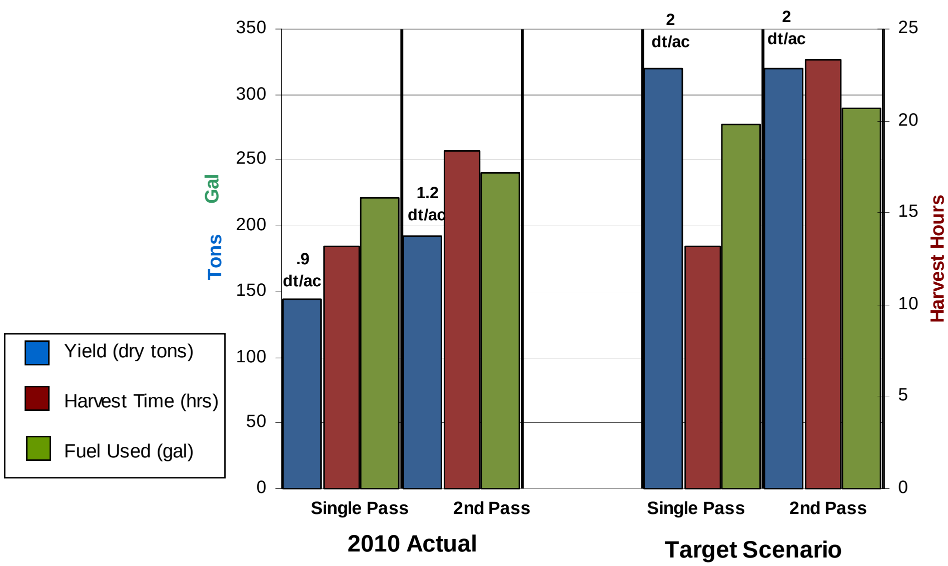
2-Technical Accomplishments/Progress/Results

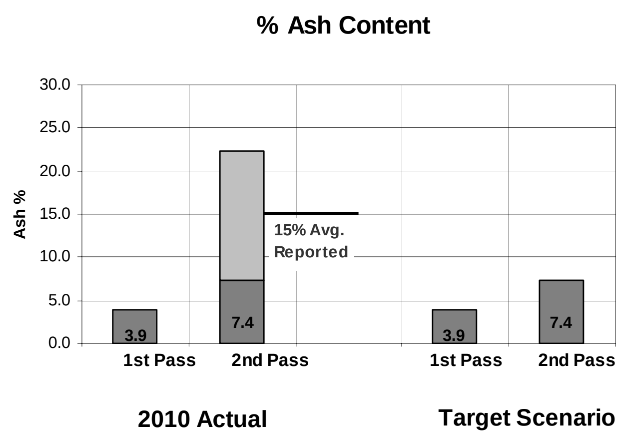
- **Tasks Executed**
  - Single pass harvesting of crop residue
  - High volume harvesting of energy crops
  - Field collection systems validated
  - Transportation system including loading and rapid securement system validated
  - Storage studies conducted

2-Technical Accomplishments/Progress/Results

Early Key Indicators

160 Acres of Iowa Corn & Biomass
190 bu/ac





	Yield (dry tons)	Harvest Time (Hrs)	Fuel Used (gal)
Current Single Pass	144	13.2	222
Current 2nd Pass (both operations)	192	18.4	240
Target Single Pass	320	13.2	277
Target 2nd Pass (both operations)	320	23.35	289

	Ash %	
Current Single Pass	3.9	
Current 2nd Pass (both operations)	7.4	15.0
Target Single Pass	3.9	
Target 2nd Pass (both operations)	7.4	

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2 - Technical Accomplishments/Progress/Results

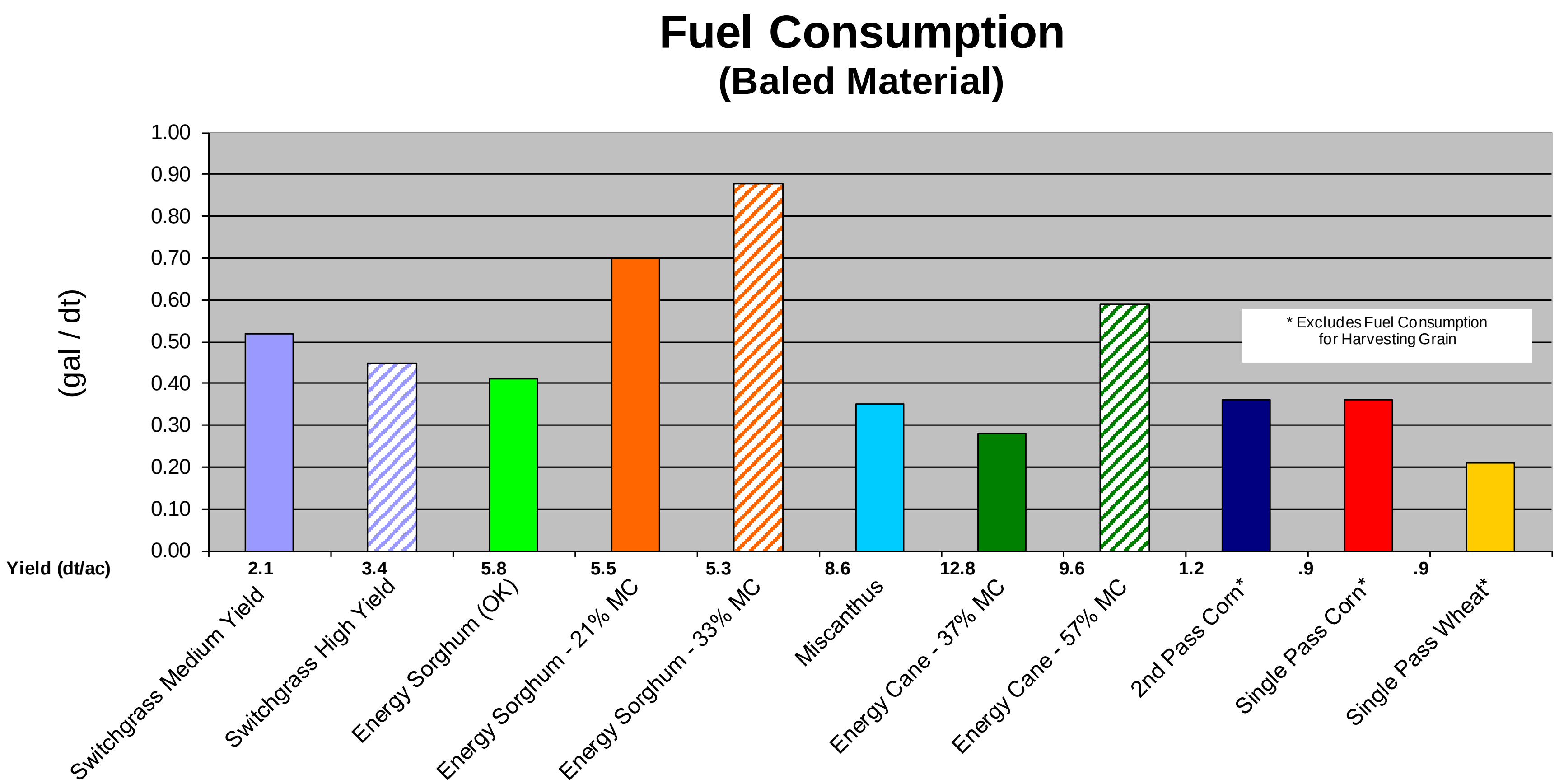
Data

Data collection and analysis resources limited data acquisition and analysis to a small portion of the total demonstration activities. Scenarios were carefully selected to represent typical conditions representing the range of production conditions.

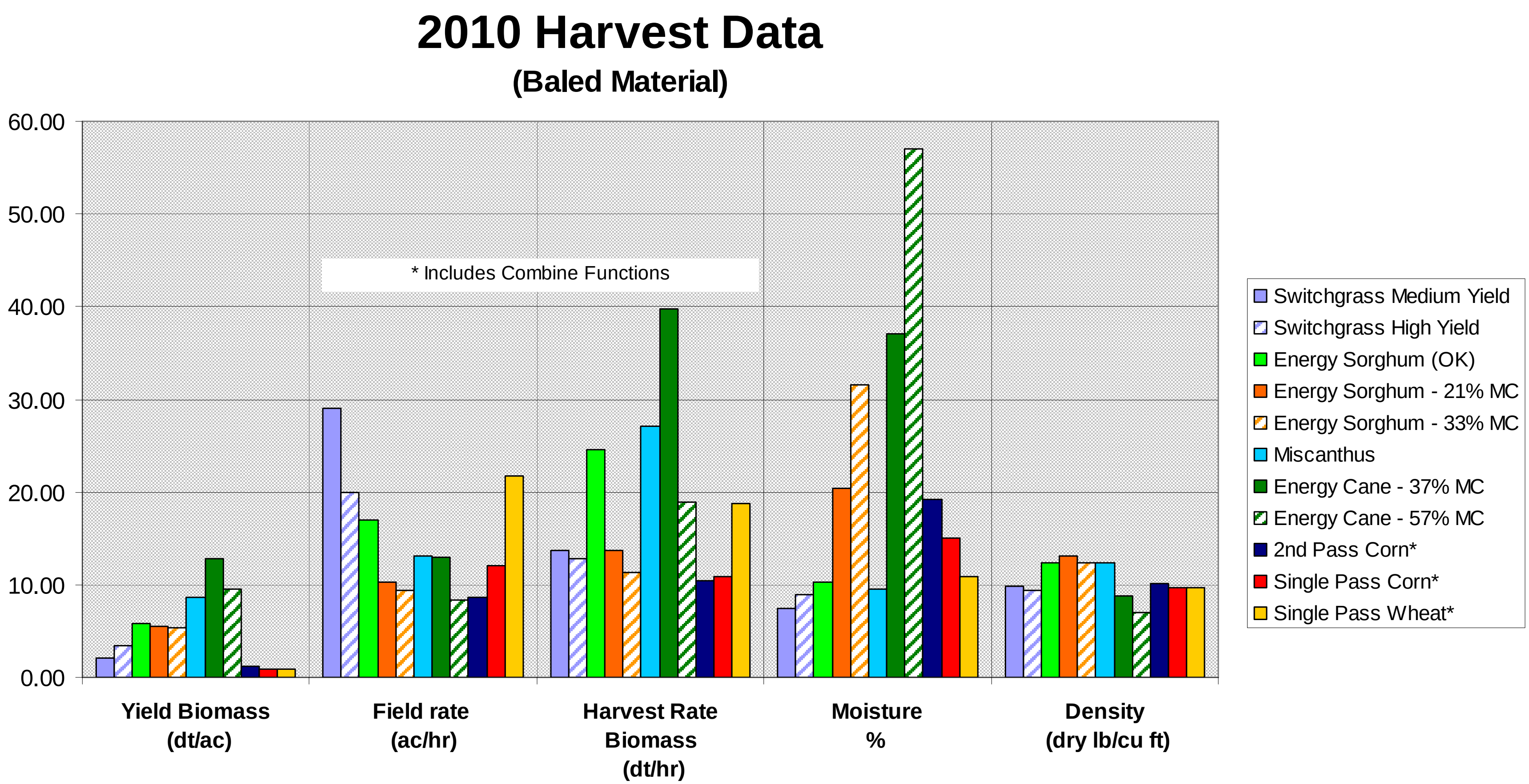
- Single Pass and 2 Pass Crop residue
  - Corn Residue
  - Wheat Straw
- 2 pass plus dedicated energy crops
  - Switch Grass, Miscanthus, Mixed Prairie Grasses
  - Energy Sorghum
- Collection and Transportation
  - Road siding
  - Transportation

2 - Technical Accomplishments/Progress/Results

2010 Harvest Data



2 - Technical Accomplishments/Progress/Results



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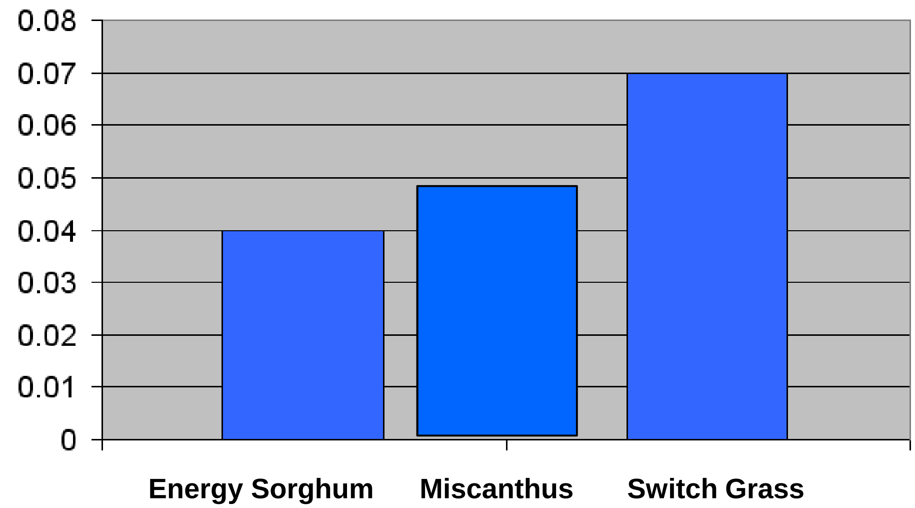
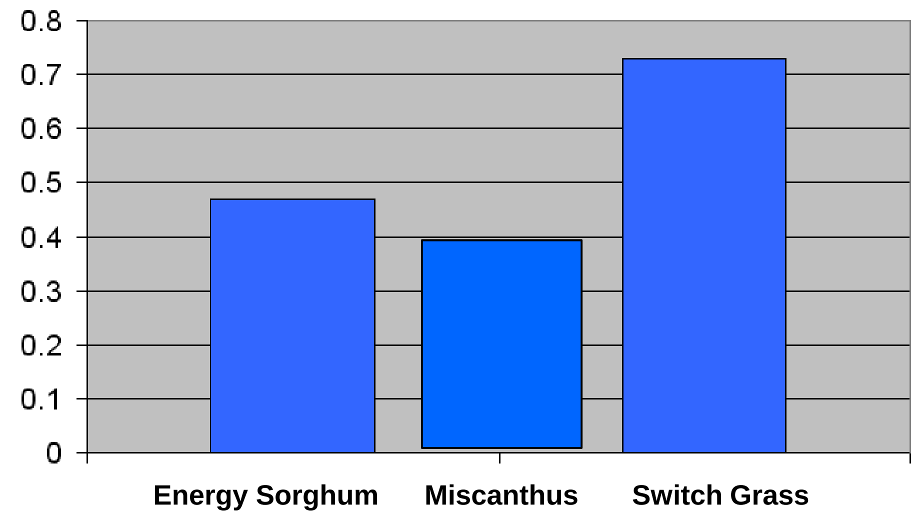
2 - Technical Accomplishments/Progress/Results

Energy Crop – Two Pass Systems, 2011

Hours/Dry Ton



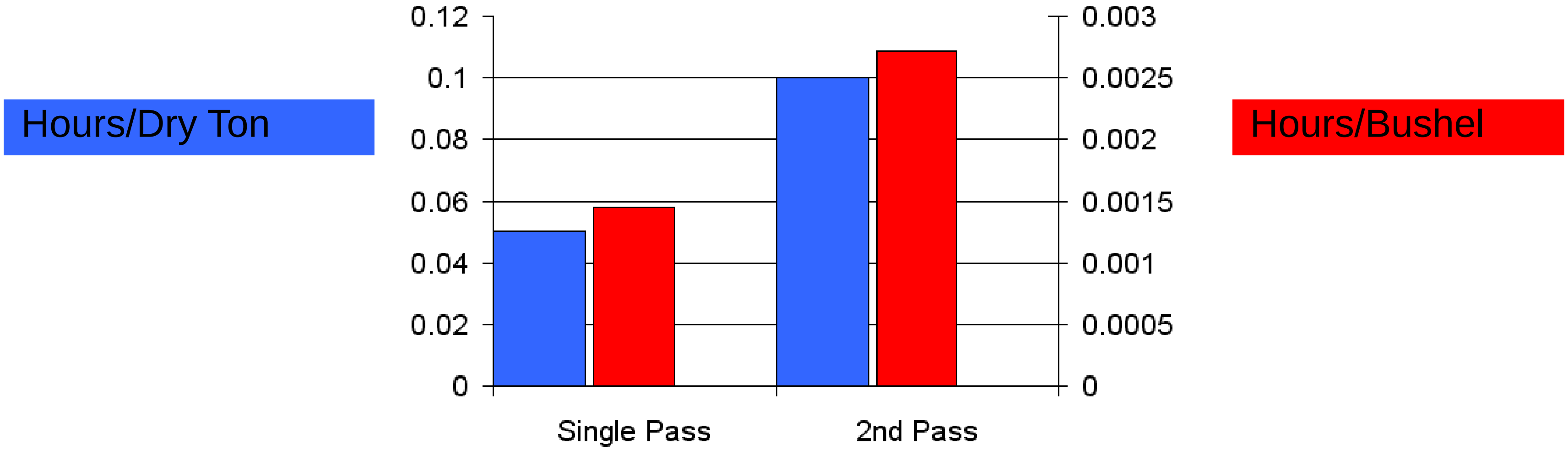
Gallons of Diesel/Dry Ton

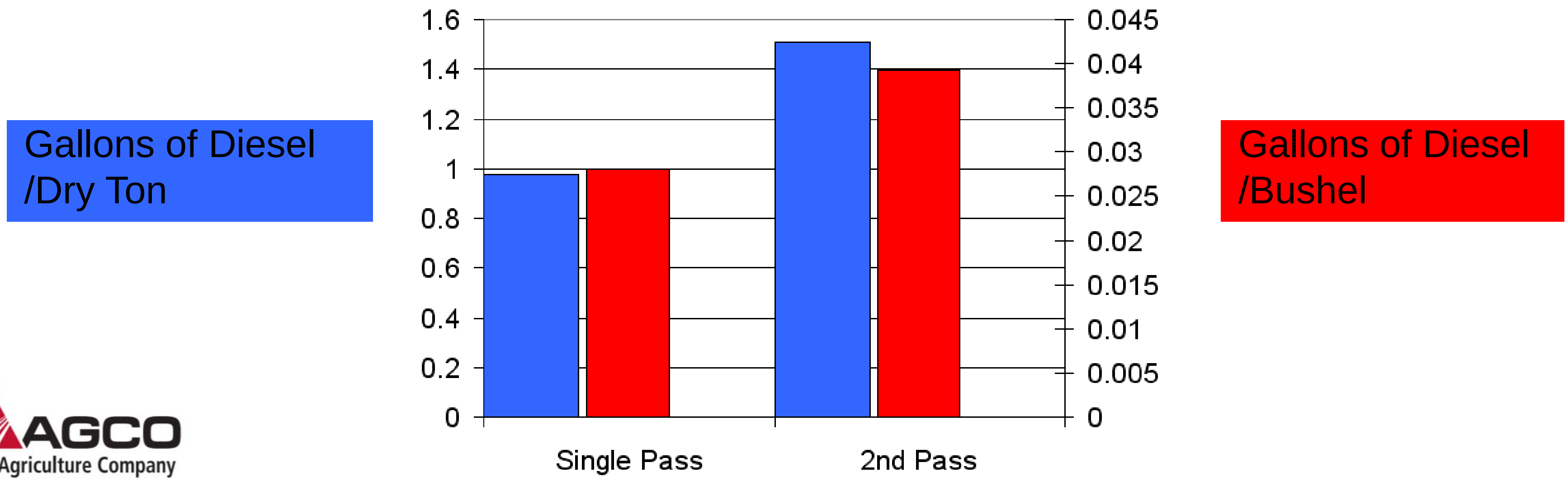


2 - Technical Accomplishments/Progress/Results

Crop Residue Data - 2011

Wheat





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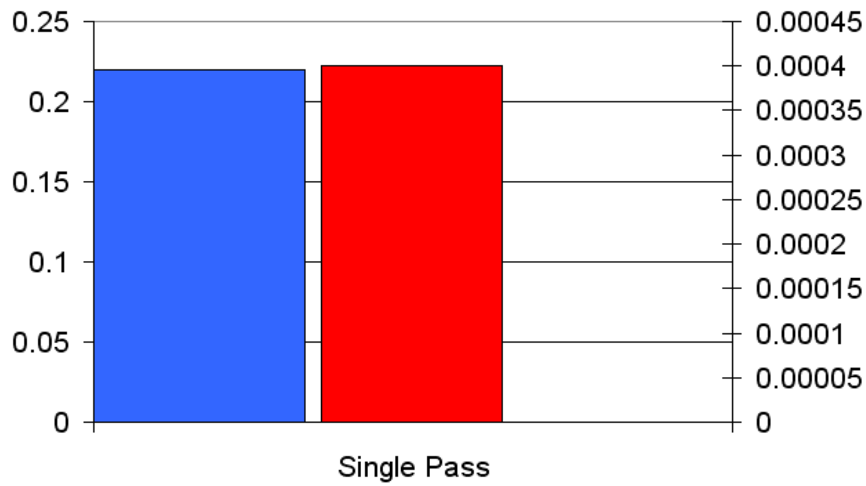
2 - Technical Accomplishments/Progress/Results

Crop Residue Data - 2011

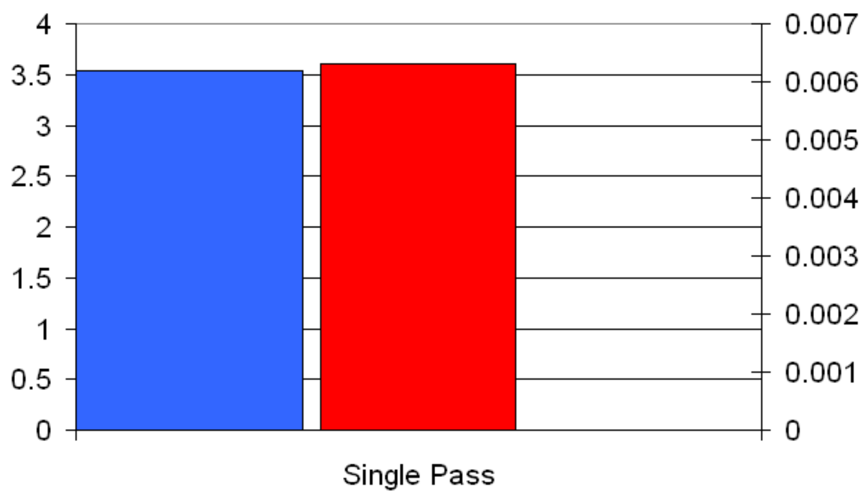
Wet Corn

Hours/Dry Ton



Hours/Bushel

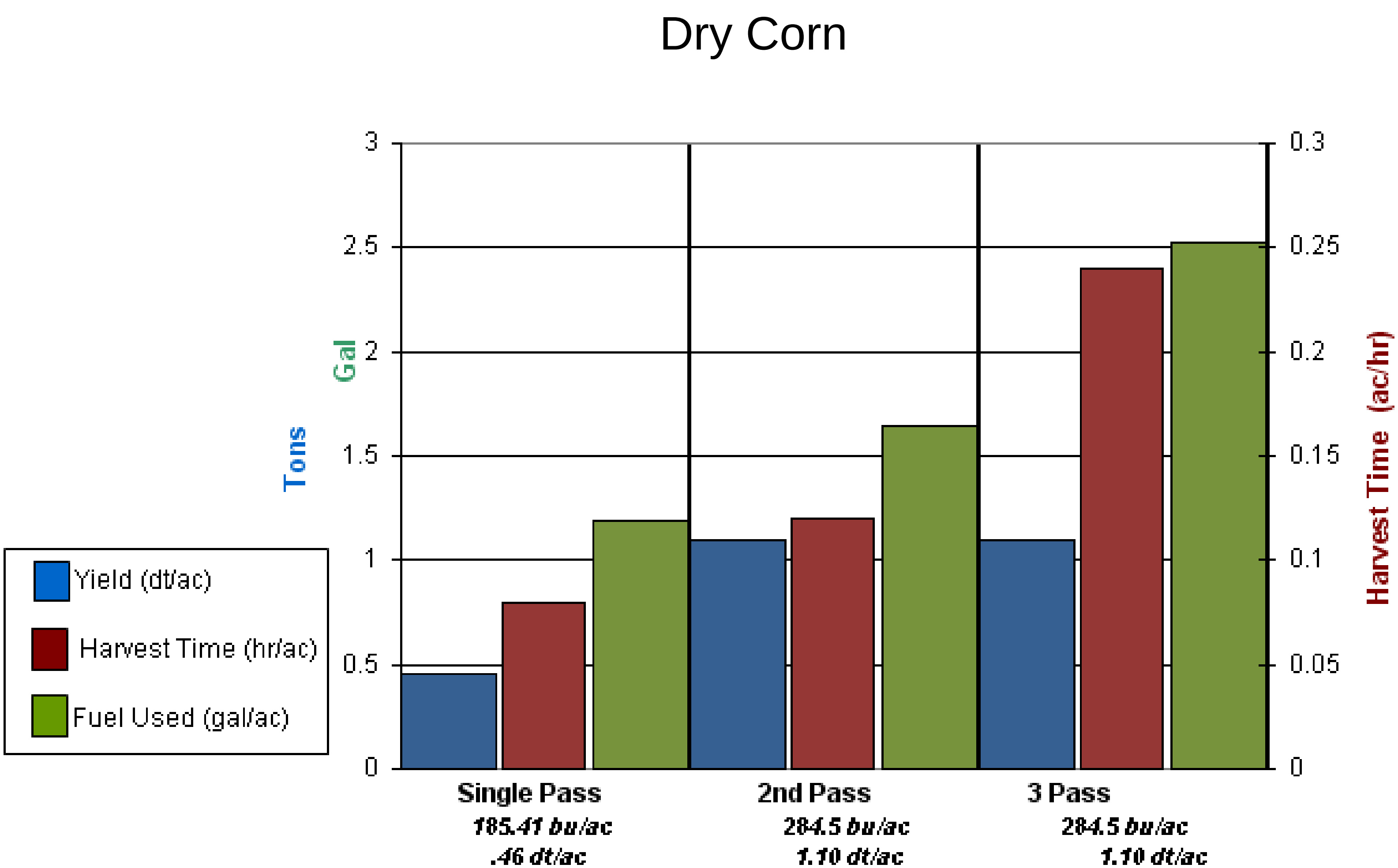
Gallons of Diesel/Dry Ton



Gallons of Diesel/Bushel

2 - Technical Accomplishments/Progress/Results

Crop Residue Data-2011



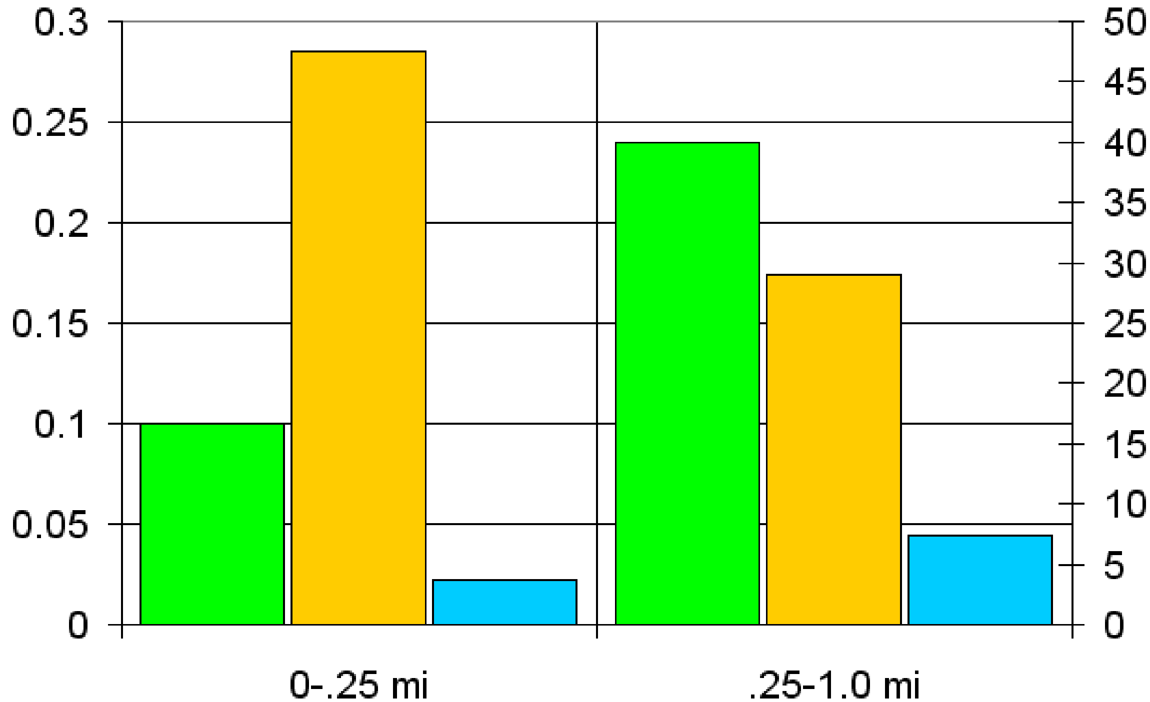
2 - Technical Accomplishments/Progress/Results

Logistics Data - 2011

Field Collection and Stacking

Gallons of Diesel / Dry Ton

Hours / Dry Ton



Dry Tons / Hour

- Roadside to Plant transportation
  - Loading and unloading systems are the largest single variable
- Targets
  - Load or unload < 10 Minutes
  - Locate storage sites on all-weather roads

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2 - Technical Accomplishments/Progress/Results

Combined Operations Reduce Total Time and Fuel

Because different operations have different rates and some have multiple outcomes, comparisons must be on a ***total input/total outpu***t basis for combined operations.

As shown in this comparison, 2-pass operations increase time requirements by 30%

Comparing Combined Operations

Typical Corn Harvest Options		ac/hr	hr/ac	gal/ac	Biomass dt/hr	Biomass hr/dt
Single Pass	Harvest Grain and Bale	10.00	0.10	1.77	6.06	0.165
		10.00				
2 Pass	Harvest Grain	13.00	0.08	1.26	5.82	0.172
	Bale	20.00	0.05	0.40	24.02	0.042
2 Pass Total		33.00	0.13	1.66	29.84	0.213
		7.88				
3 Pass	Harvest Grain	13.00	0.08	1.26	5.82	0.172
	Windrow Stover	8.50	0.12	0.87	9.35	0.107
	Bale	20.00	0.05	0.40	24.02	0.042
3 Pass Total		41.50	0.24	2.53	39.19	0.32
		4.09				

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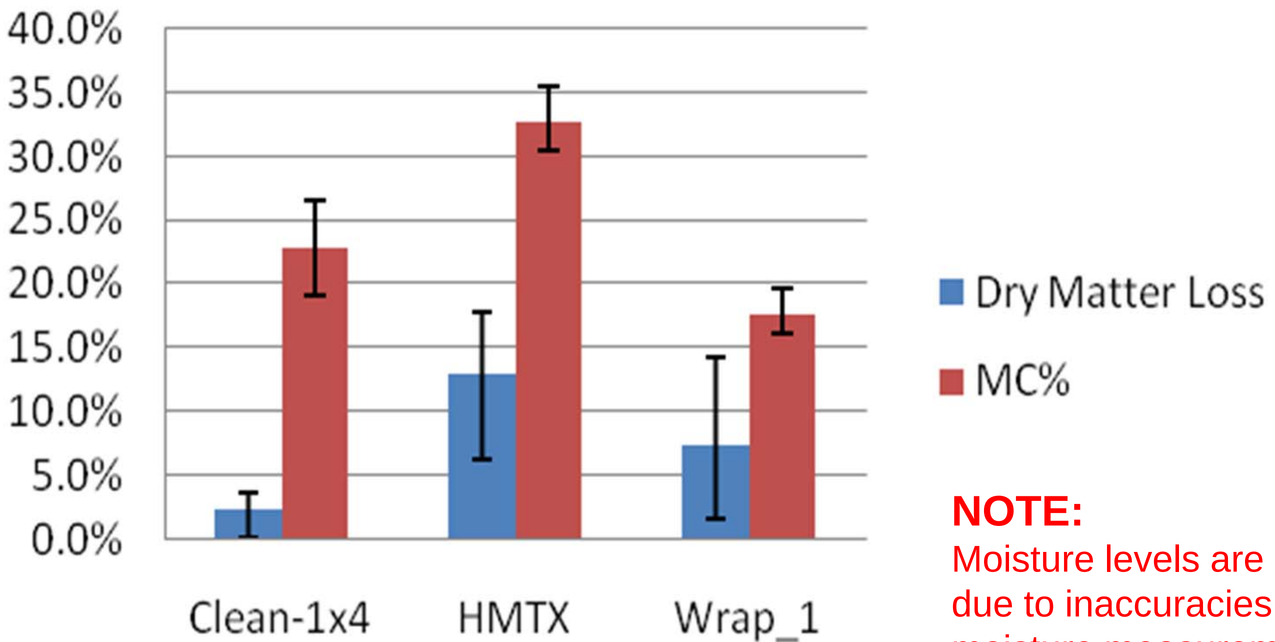
2-Technical Accomplishments/Progress/Results

2010 Corn Residue Storage

After 3 months



Initial MC	15%	33%	12.4%

NOTE:
Moisture levels are suspect due to inaccuracies in field moisture measurement. Moisture migration in storage requires more advanced methods of sampling.

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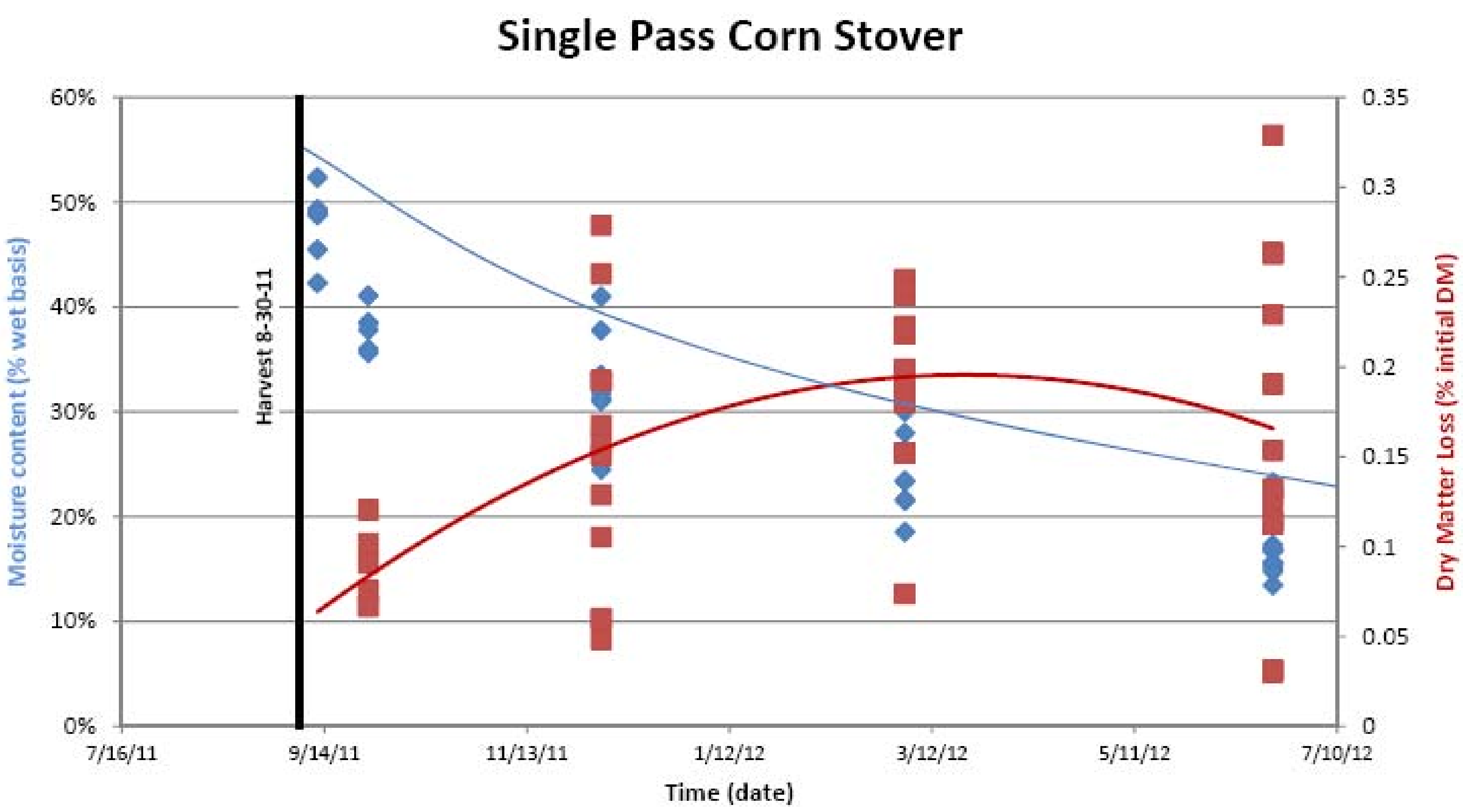
2-Technical Accomplishments/Progress/Results

Moisture & Dry Matter Loss



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2-Technical Accomplishments/Progress/Results

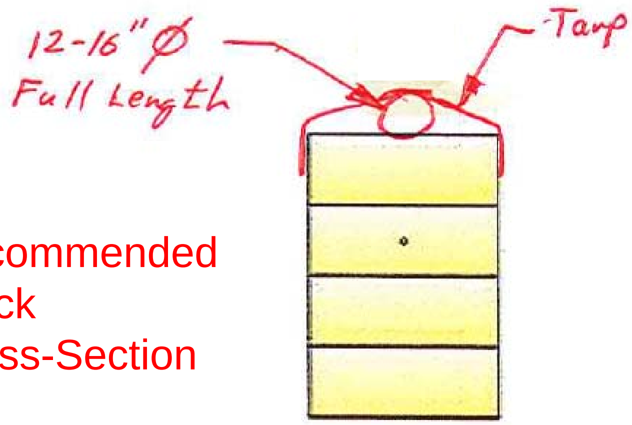
Storage Conclusions

- Higher Initial moisture contents experience higher Dry Matter loss
- Higher Initial moistures result in increased bale compression and loss of bale integrity
- Dry Matter loss is the result of both biological activities and physical material loss from bales during storage and handling
- Theoretical ethanol yield in corn stover baled and stored at varying moisture contents was found to be a function of Dry Matter loss. Yields were calculated using NREL conversion efficiencies to be 83-86 gal/dt from material at the time of processing with no significant difference due to moisture content other than higher Dry Matter losses at higher moistures

2-Technical Accomplishments/Progress/Results

Best Practice Storage Methods

- North-South orientation to prevent differential heating and resulting moisture migration to the cool side of stacks
- Cover to shed precipitation but create vented air space between cover and top of stack to prevent moisture concentration under cover
- Place on level drained site with provision for runoff to drain away
- Limit stack height to 4 bales high to prevent excessive bale compaction and resulting loss of integrity
- Site storage locations to facilitate efficient loading of trucks and adjacent to all weather roads



Recommended Stack Cross-Section

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3 - Relevance

- Systems demonstrated are compatible with agronomic practices and transportation considerations.
  - *Large Square Bales and the Stinger ALSS system received thumbs up from the Iowa DOT in demonstrations vs. round bale systems.*
  - *Densities in as harvested crops were sufficient to fully load trucks at highway load limits.*
  - *Harvest rates up to 50% of corn residue meet all erosion and soil organic carbon requirements for Iowa Corn*
- Systems demonstrated provide a pathway for rapid adoption at minimal equipment costs using equipment with a high degree of commonality providing the opportunity to limit equipment costs
- With market demand, Harvest and Logistics systems are available in 2013 & 2014 supporting the DOE MYPP, supplying the necessary quantities at costs that are reasonable for producers and converters

Economical & Sustainable Corn Residue Removal Rates are achievable

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4 - Critical Success Factors

- Equipment capable of harvesting high volume energy crops is available
- Economical harvest rates align well with agronomically sustainable harvest rates for corn and in some cases actually result in increased yield levels
- Logistics systems characterized by efficient handling and safe highway transport are available and compatible with local infrastructure promoting public acceptance
- Producers have demonstrated they will participate if prices provide positive cash flow
- Minimizing ash and capturing high quality feedstock will be critical to conversion operations and lowering costs of conversion
- Best practice storage methods will ensure feedstock quality and maximize useable yields
- Consistent public policies will be required for producers to invest in equipment and/or dedicated crop establishment

Future Work through 30SEP13

- Complete analysis of data
- Prepare final report
- Make production releases on equipment as market demands justify
- Continue product development to realize performance improvements as market needs indicate

Summary

- **Approach**

  Project demonstrated use of commercially available equipment systems to facilitate rapid adoption to meet DOE MYPP objectives

- **Technical Accomplishments**
  - Development and validation of a single pass crop residue harvesting system
  - Development and validation of high volume energy crop headers with advanced conditioning
  - Development of balers with enhanced densities
  - Validation of high speed loading and a load securement transportation system

- **Relevance**

  Project has demonstrated commercially available equipment systems capable of economically supplying commercial scale Bio-Conversion facilities -- stem to throat

Summary

Miscanthus Harvest

High Speed Loading

Single Pass Crop Residue Harvest

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Summary

- **Success Factors**

  Successful use of systems in commercial scale production settings demonstrates the project's success

- **Challenges**
  - Increasing crop residue harvest rates to economical levels
  - Educating producers on methods/systems to achieve economical harvest rates while maintaining agronomic sustainability and meeting societal expectations.
  - Drying of energy crops harvested at high moisture(energy sorghum)
  - Density and bale formation opportunities exist to reduce long term loss of bale integrity in higher moisture content bales (>30%)
  - Methods and equipment to further increase density in crop residues
  - Development of methods and equipment for accurate large sample moisture and ash measurement, required for feedstock quality assessment

Summary

- **Future Work**
  - Corn heads with selective high take rates for prescription harvesting are in development, commercializing the concepts demonstrated in the project
  - Energy crops such as switch grass and miscanthus, which dry standing in the field during dormancy, could be harvested more efficiently with development of a single pass harvester to cut and package simultaneously
  - Further increases in bale density will decrease storage and handling costs and to a lesser degree transportation costs
- **Technology Transfer**
  - High throughput Combine suited to high residue harvest rates is now in production
  - High density packaging - AGCO's Extra Density Baler was placed into full production in 2012
  - AGCO's Biomass Windrower Header is in production in 2013 for high volume crop harvesting of crops like energy cane and miscanthus

Are there any Questions?

Additional Slides

Publications and Presentations

PRESENTATIONS

Presenter: Maynard Herron, AGCO Corp.

1) Bio based Products and Bioenergy
   Bio based Products and Bioenergy Multi-University Graduate Program Planning workshop
   Oklahoma State University, Stillwater, OK
   March 1, 2010

2) Challenges in Harvesting and Storing Stover
   2011 Agricultural Equipment Technical Conference
   Atlanta, Georgia
   January 6, 2011

3) Equipment display and video presentation of field activities @ Biomass 2011 Conference
   National Harbor Washington, D.C.
   July 27-28, 2011

Publications and Presentations *con't*

4) Considerations for Biomass Production and Harvest #1111437
   2011 ASABE Annual International Meeting
   Louisville, KY
   August 8, 2011
5) Biomass Supply Systems, Harvest & Logistics
   Kansas State University, Biotechnology Graduate Student Seminar
   Manhattan, KS
   February 9, 2012

6) Challenges in Harvesting and Storing Stover
   2012 ASABE Annual International Meeting—Supply of High Tonnage Feedstock
   Dallas, Texas
   July 31, 2012

7) Field Performance of Commercial Biomass Harvest Equipment #121337614
   2012 ASABE Annual International Meeting
   Dallas, Texas
   July 31 2012

2011 Feedstock Peer Review Actions

Responses to Previous Reviewer's Comments

➢ **Limited Data Available**

- Additional data sets have been taken on representative scenarios in all crops.
- Uniform or standardized samples were found to be very difficult to obtain due to the influences of weather, location, producer practices, and yields.
- Even though significant efforts were made to identify comparable conditions the results still require significant judgment to understand what are good comparisons between conditions and what are not.
- As a general statement it is felt the data obtained is typical however +/- 25% deviations are within the range of normal variations.

2011 Feedstock Peer Review Actions

Responses to Previous Reviewer's Comments

- **Storage**
  - Substantial efforts were made to quantify the influence of storage on final yield from feedstocks
  - Best practice concepts were demonstrated although a good portion of the analysis was by subjective measures with analytical studies on a limited number of storage trials
  - Analytical results indicate that final energy yields can be predicted accurately by determining dry matter loss. While dry matter loss determination methods need improvement, subjective observations give very good relative indications.
- **Sustainability**
  - Observations by experienced Farmers and Agronomists is a primary measure and all agree the methods are on target
  - Long term agronomic studies by Pioneer in Northern Missouri collaborate the effects of partial residue removal in continuous corn. Over a 4 year period, yields were increased an average of 15% with 50% residue removal vs. 0% removal, increases ranged from 4-52 bu/ac.

2011 Feedstock Peer Review Actions

Responses to Previous Reviewer's Comments

- **Competitive Equipment Comparisons Lacking**
  - AGCO equipment was on occasion operated alongside competitive equipment.
  - Differences in performance between competitive machines, where comparable machines exists, is insignificant compared to differences between operators, operational modes, and general maintenance practices
  - Tying system performance of balers is the single biggest factor affecting productivity
- **Technology Transfer & Collaboration**

  Information transfer is occurring through numerous channels
  - Demonstrations with Producers
  - Technical presentations to Professional and Academic Groups
  - Articles in Ag Media Journals
  - Commercial offering of some products resulting from the project is occurring

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