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Harvesting, Handling, Transportation and Storage

Stephen W. Searcy, P.E.

Biological and Agricultural Engineering

Texas A&M University & Texas AgriLife Research

Improving Life through Science and Technology.

Background & Biases

- Expertise in machine system development with emphasis on cotton and biomass logistics
- Research is focused on energy sorghum, with some switchgrass and crop residue
- Collaboration with ag machinery companies

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Biomass Supply Chain

- Expected to provide feedstock of
  - Required quantity
  - Required quality
  - Timely delivery
  - Sustainable cost

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Logistics Myths/Assumptions

We have been mechanically harvesting biomass for decades. There are no significant technical barriers.

True – if you don't care about cost

False – if we want biomass to replace fossil fuels

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Logistics Myths/Assumptions

Cellulosic biomass is all pretty much the same, so the conversion plant will take most anything.

False – Collection, storage and processing operations all impact the biomass quality and energy recovery.

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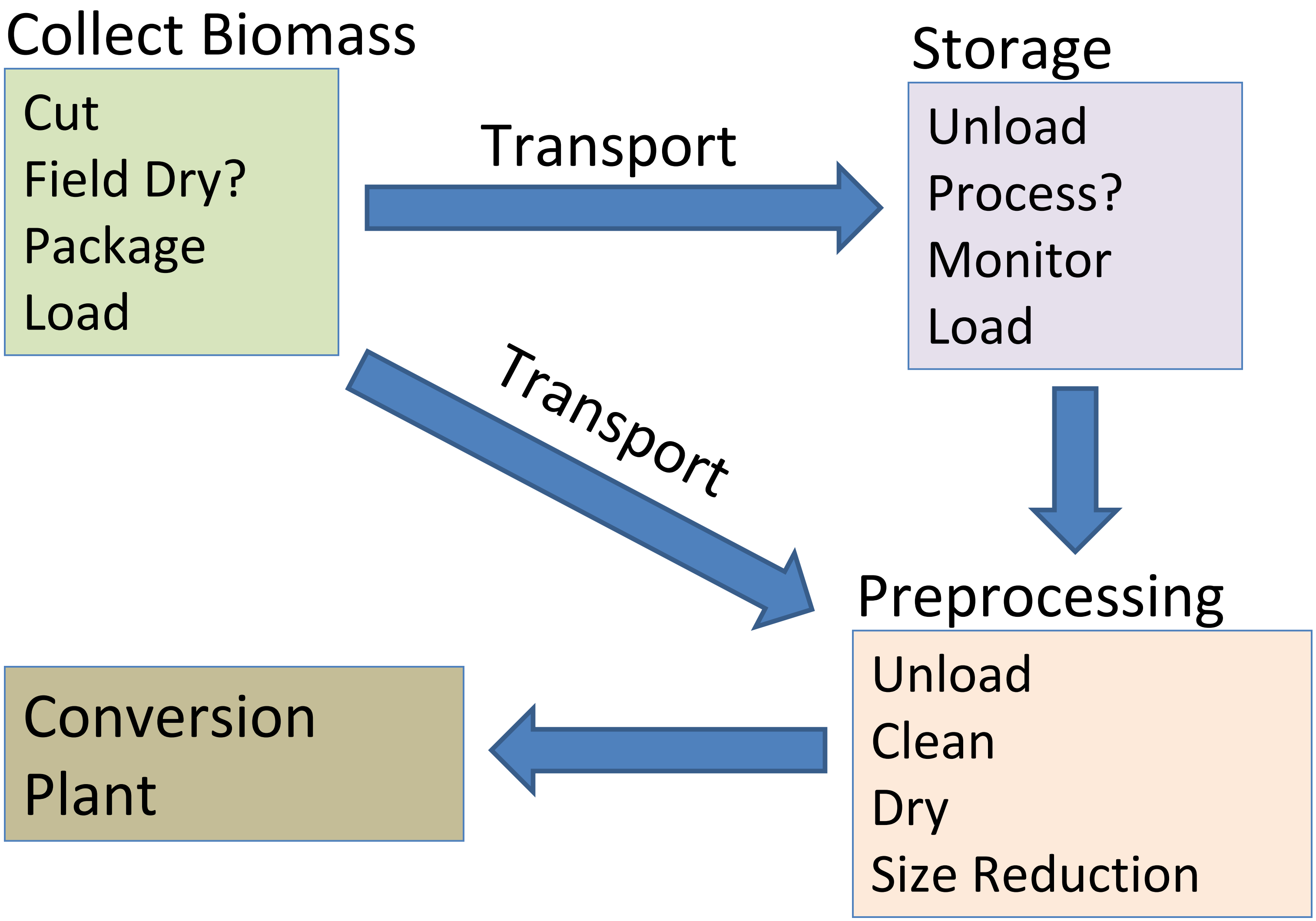
Logistics Myths/Assumptions

Moisture content doesn't matter much if the haul distances are short.

False – Biomass harvested at 75% MC requires three times as many trips (trucks and drivers) as 25% MC material.

Biomass Supply Chain Operations



Supply Chain Principles

- Improve energy density at every operation
  - Field – maximize bulk density
    - Field dry to increase DM concentration
    - Compress to higher density in package
  - Regional – maximize energy density
    - Convert to energy form as close to field as possible
    - Leave conversion residues distributed

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Supply Chain Principles

- Maintain biomass quality under varying moisture content at harvest
  - Carbohydrates consumed during storage result in lower energy content and higher ash
  - Mold may inhibit biochemical conversion efficiency

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Supply Chain Principles

- Minimize machine system cost
  - Extend machine capacity with longer harvest season, higher efficiencies and low labor cost (custom operation model)
  - Take advantage of underutilized resources (individual farm model)

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Supply Chain Principles

- Packaging method must provide
  - Enhanced handling
  - Extended storage period
  - Provide maximum legal truck loads
  - Minimum labor and load/unload times

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Biomass Logistics Selection

The optimum feedstock supply chain is influenced by

- Feedstock properties
- Local conditions (weather, labor market, etc.)
- Conversion process used
- Business model

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Feedstock Influences

- Crop residues
  - Limited harvest window
  - Uncertain moisture content
  - Constraints of and on primary harvest objective
  - Net yield after conservation requirements uncertain

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Feedstock Influences

- Perennial feedstock crops (switchgrass, miscanthus, arundo, etc.)
  - Potentially longer harvest window
  - Dry matter loss more critical since biomass is only source of value
  - High yields and crop physical characteristics influence drying rate

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Feedstock Influences

- Annual feedstock crops (energy sorghum)
  - Variety selection allows long harvest season
  - Dry matter loss more critical since biomass is only source of value
  - High yields and crop physical characteristics influence drying rate

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Conversion Influences

- Thermochemical
  - Smaller particle size required
  - Moisture content more critical
- Biochemical
  - More forgiving of particle size and moisture content
  - pH can affect enzymatic processes

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Business Model Influences

- Custom Harvest Model
  - Farmer grows biomass, contractor schedules and performs all harvest operations
  - Based on high capacity machines, minimal labor
- Farmer Harvest Model
  - Farmer performs all operations
  - Utilizes available resources for low cost

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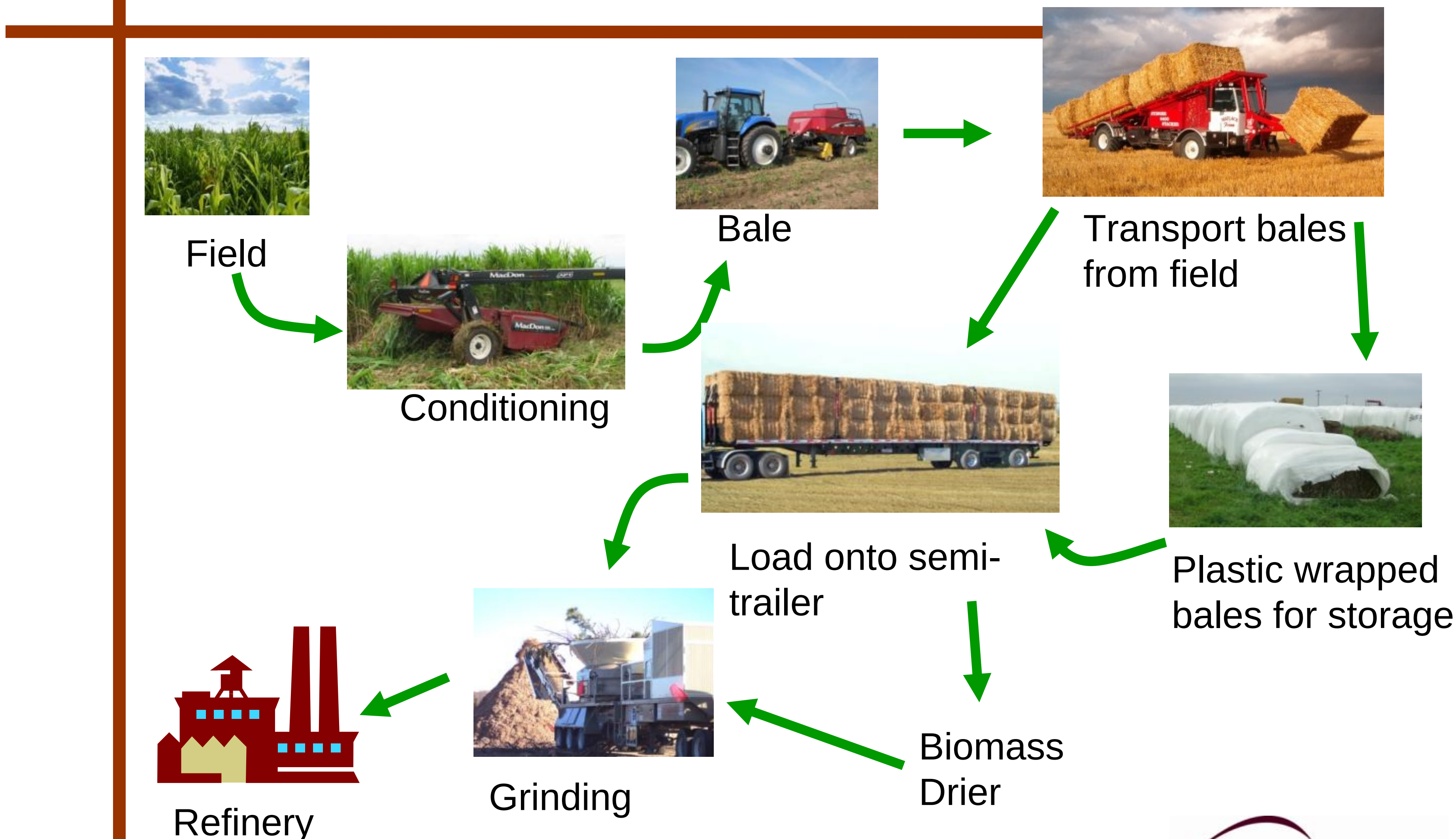
1st Generation Logistics



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Mower/Conditioners
Photo courtesy of Carol Jones, Oklahoma State University

Commercial Units in Biomass

- High yield may require slower speeds
- High yield can result in poor conditioning
- Harvest efficiency can be reduced
- Difficulty with lodged crops, a frequent occurrence with dedicated energy crops

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MoCo Experiences

- Texas – energy sorghum
  - Compared four commercial designs
  - All experienced generally similar results

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Harvesting Equipment

- Four Windrower/Conditioners
  – MacDon M200 with Auger Header
  – MacDon M200 with Disc Header
  – John Deere 4995 with Flail Conditioner
  – John Deere 4995 with Tri-Lobe Conditioner

*Both MacDon machines had “N bar” conditioner rolls

*Both John Deere machines had rotary disc headers

Results

Avg. Windrow Efficiency

	D3	DF	MA	MD	Cutting Avg.
Aug 1st Cutting	92.8% B	93.3% AB	95.9% A	95.7% A	94.4% A
Aug 2nd Cutting	93.6% B	91.9% B	96.9% A	93.4% B	93.9% A
Oct Cutting	82.3% B	72.2% C	86.5% AB	88.6% A	82.3% C
Nov Cutting	*	*	82.4% A	83.5% A	83.0% C
Jan Cutting	88.3% A	#	82.6% A	91.8% A	87.9% B
Machine Avg.	**90.8% A**	**88.4% B**	**92.5% A**	**92.1% A**	

Row means with same letter are not significantly different.

* John Deere machines were not available for November cutting.

The Jan Cutting DF area was not sampled from because of lack of machine performance.

MoCo Experiences

- Oklahoma – energy sorghum
  - Performed well in standing crop
  - Higher losses when lodging
  - Required two weeks to dry to safe moisture
- Oklahoma – switchgrass
  - Performed well in yields of 8+ DMT/ac
  - Achieved 12% MC after only one day

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Rakes

Raking Experiences

- Texas – energy sorghum
  - Used to enhance drying for yield of 10-12 DMT/ac
  - Performance degraded by uncut stalks and random oriented long stalks
  - First windrow turning – 0.25-0.5 mph
  - Subsequent turning – 8-10 mph

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Balers

Baling Experiences

- Texas – large square sorghum bales
  - Generally good performance
  - Difficulty with pickup teeth, attributed mainly to problems with uncut stalks
  - Problems with plugging when windrows are wider than pickup

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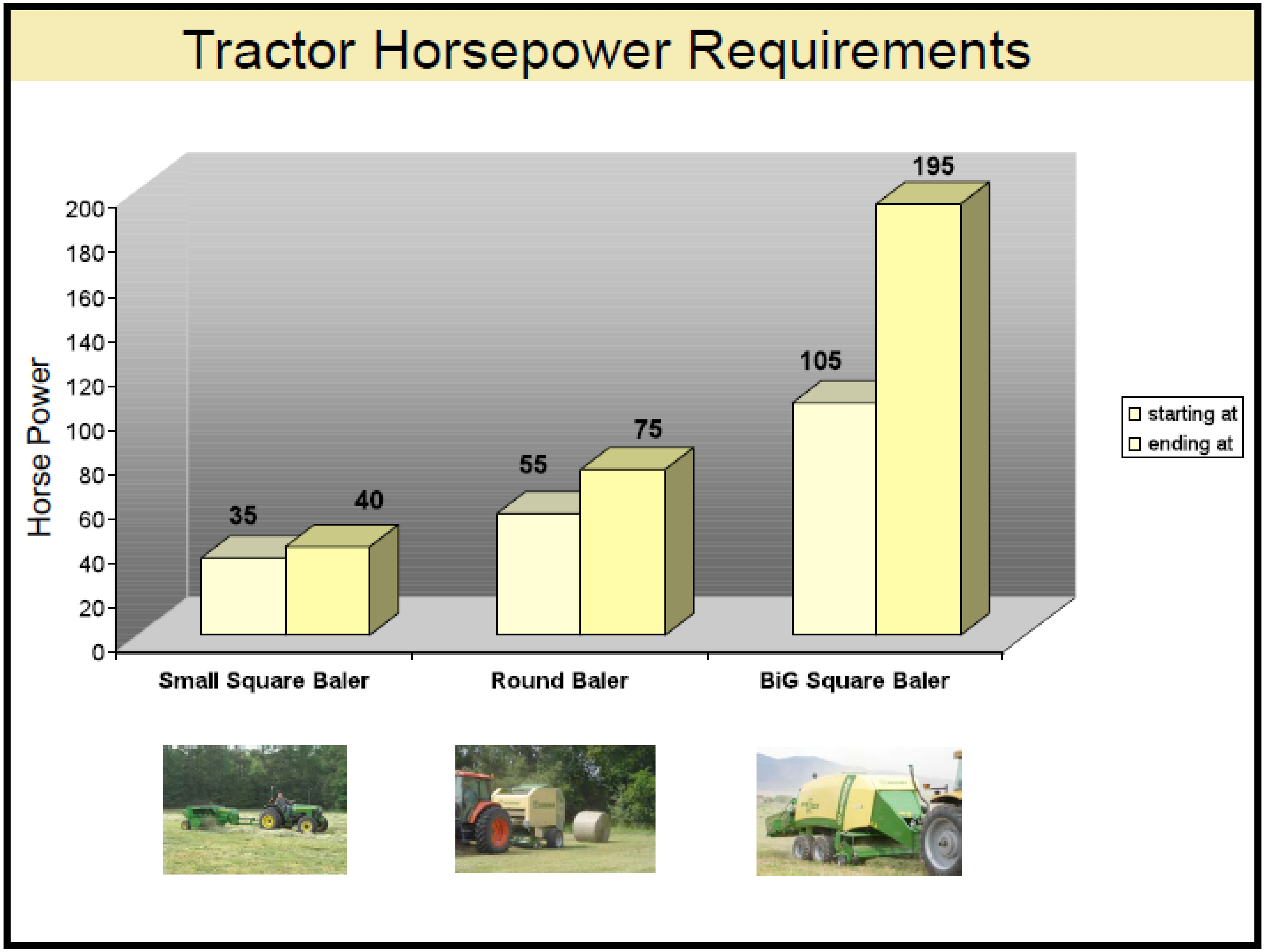
Baling Experiences

- Oklahoma – large square bales
  - Generally good performance with both sorghum and switchgrass
- Oklahoma – large round bales
  - Typically poor bales in switchgrass due to low densities

Baling Power Requirements



Source: Krone Big Pack-Equipment.pdf

Photo courtesy of Matt Darr, Iowa State University

Bale Handling

- Equipment developed for hay handling functions equally well with biomass bales
- Capacities may be limited due to bale weights, particularly with high MC
- Time to load a semi-trailer is 20-30 minutes

Telehandlers for Energy Crops?

Source: Krone Big Pack-Handling.pdf

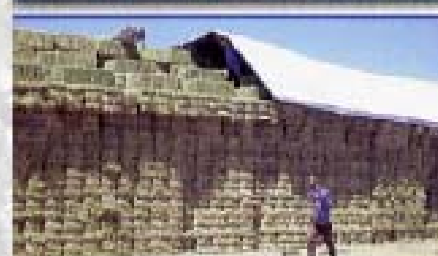
STORAGE











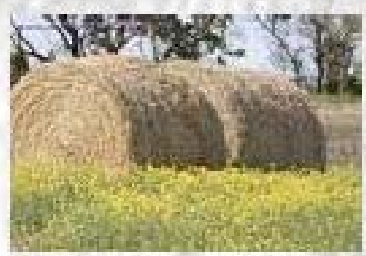


Image source: Krone Big Pack-Shipping & Storage.pdf

Storage

- Excellent work done by Oak Ridge National Lab
- Choice is cost trade off: $ invested vs. $ lost in DM
- Options range from uncovered storage of round bales to storage buildings
- No significant difference from hay
- Major issue is wet bale storage

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Forage Harvesters

Image source: www.claas.com, 8/25/10

Forage Harvesters

- Adequate capacity in current models
- Standing crop – row-independent headers
- Field dried crop – windrow pickups
- Combines harvest and particle size reduction operations

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New Holland


Theoretical chop length is only an indicator
of the distribution of particle sizes

Storage

Image source: http://www.bridoncordage.com/images/silage_bag.jpg

Storage of Chopped Biomass

- Alternatives similar to silage systems with same advantages and disadvantages
- Major additional disadvantage is need to remove from storage and haul to conversion site
- Less than maximum DM loads due to low DM density in trailer

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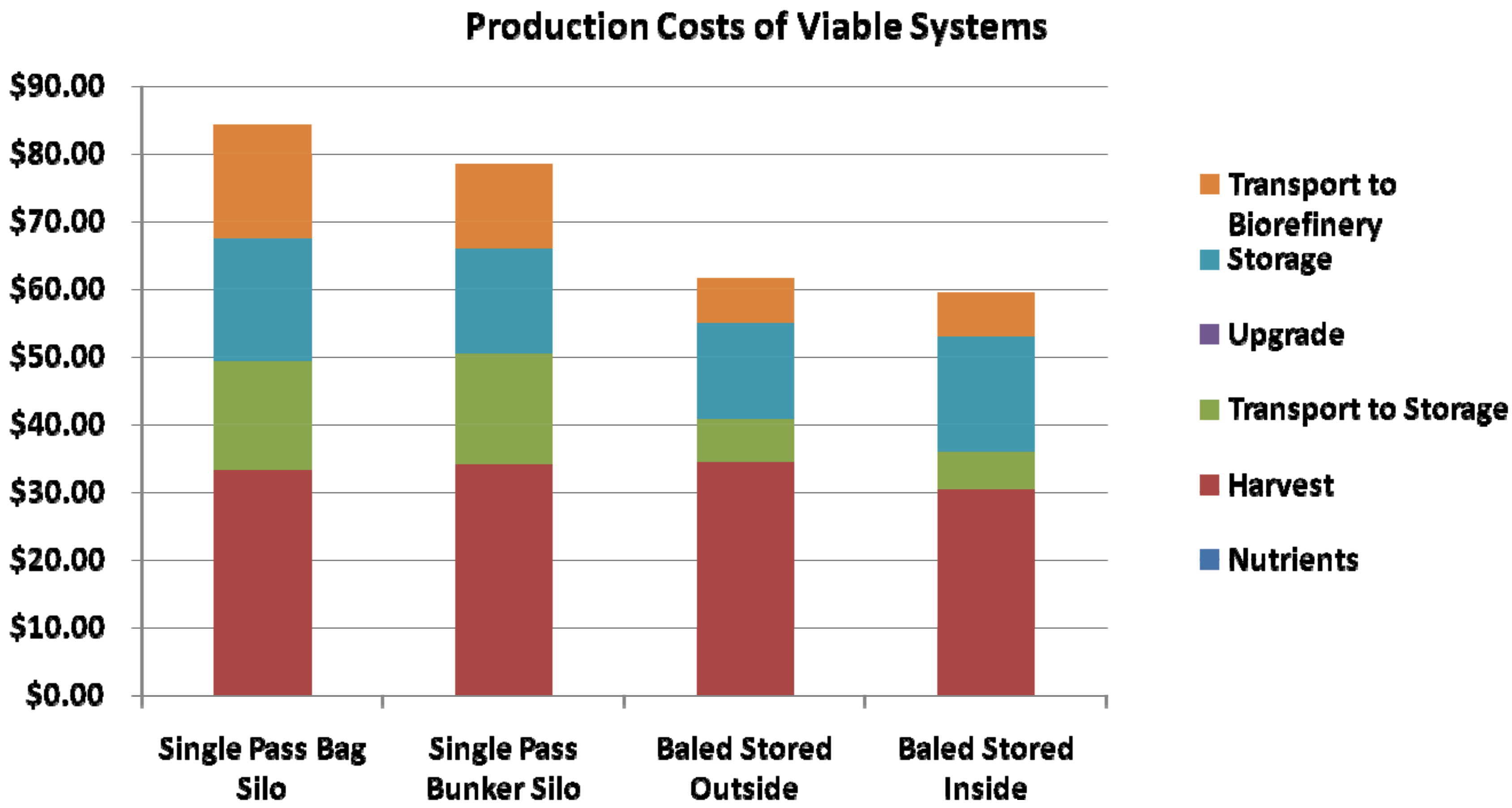
2nd Generation Logistics

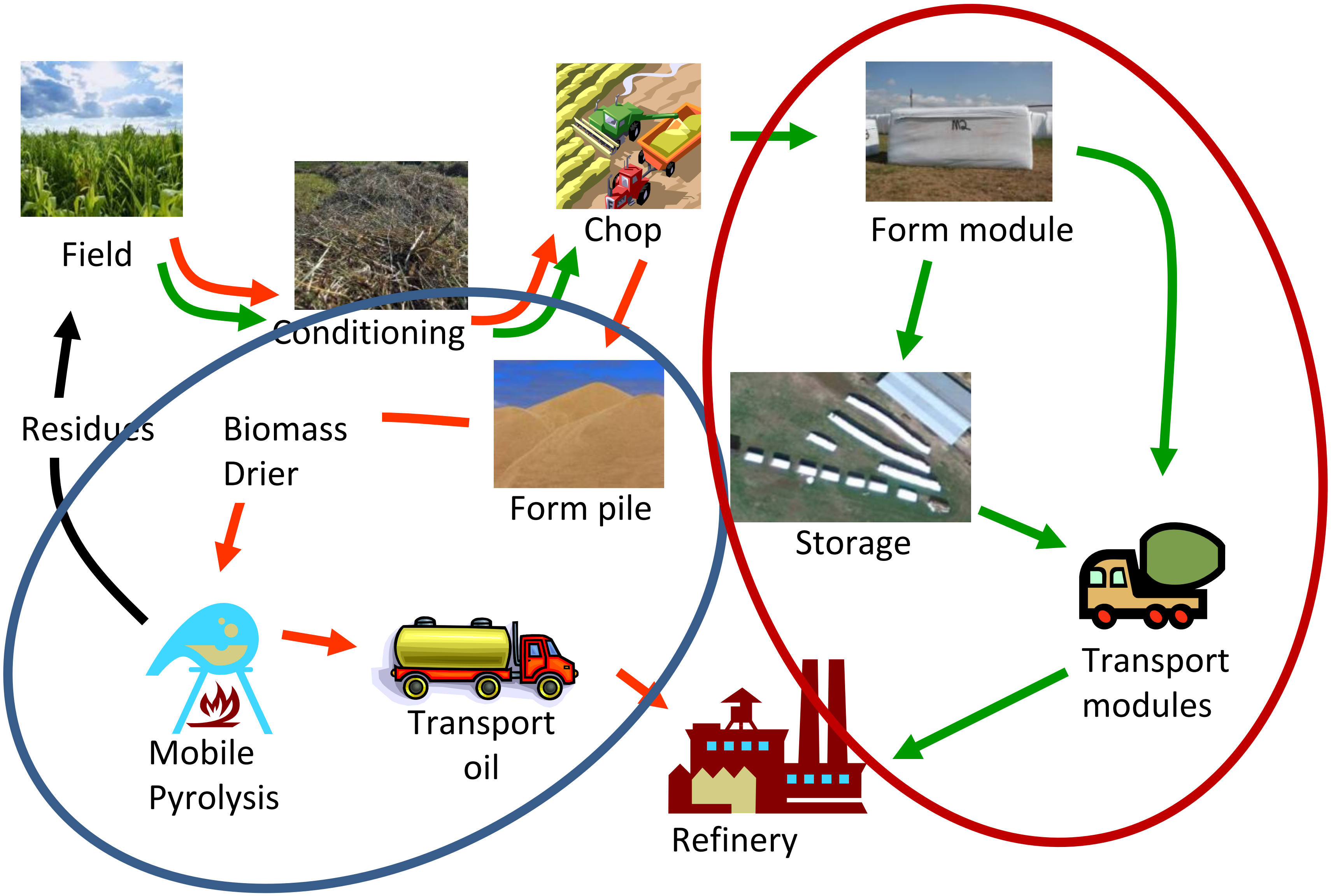
Single Pass Harvesting Technologies

- Positives
  - Allows flexible and selective collection
  - Provides greatest percentage of harvestable material
  - Can collect stover or cobs only
- Negatives
  - Reduces harvest capacity of combine
  - High in-field logistics needs

Current Production Costs



2nd Generation – Texas Activities



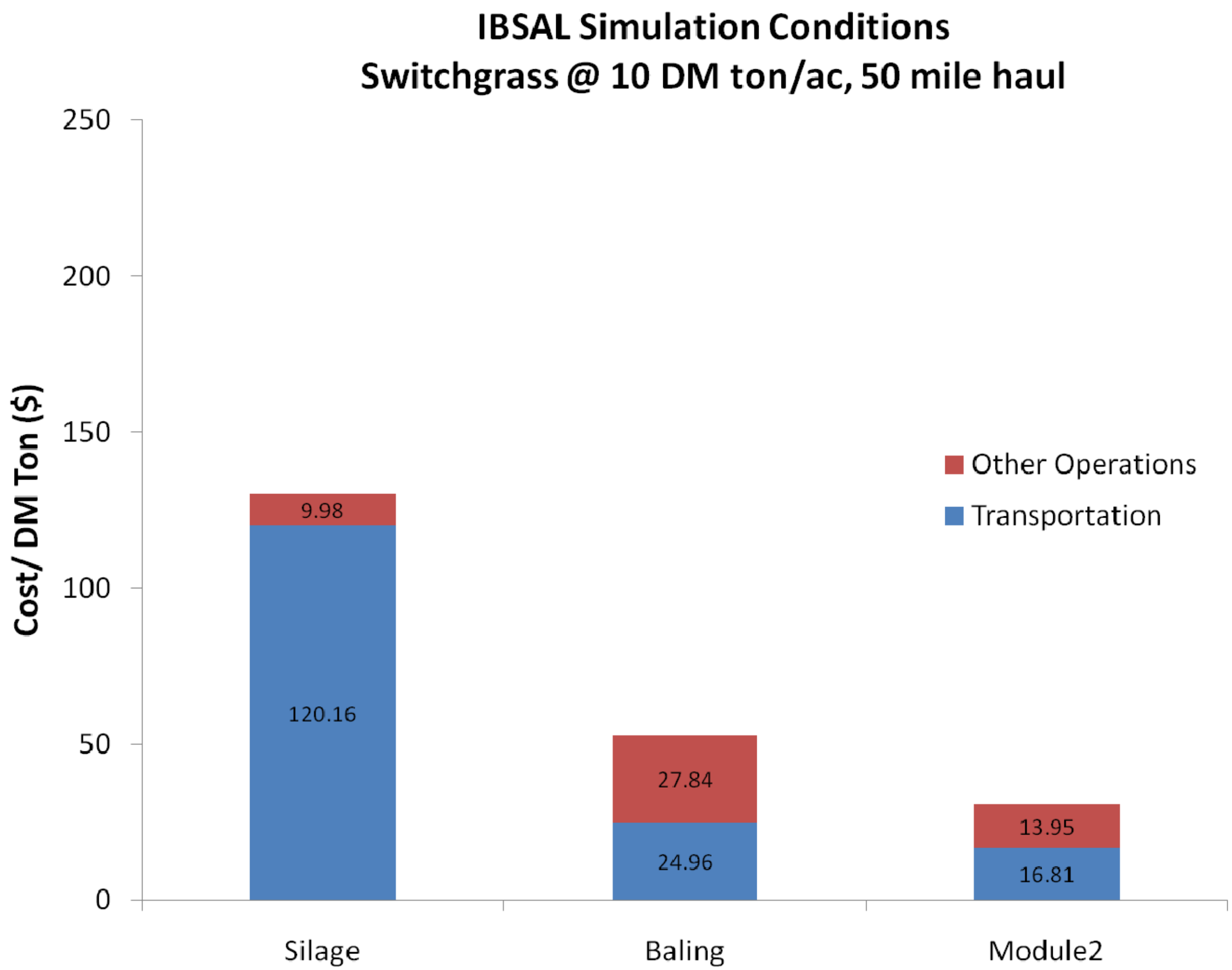

Moisture Insensitive System of
Large Anaerobic Packages Based
on Silage/Cotton Operations


Loading and Unloading
Energy Sorghum Package

Results to Date

- Proof of concept with cotton equipment – labor intensive
- Proof of concept packages – 4-5 DMT
- Load/unload package in 90 seconds
- Package maintained form after 60 miles of transport
- 85% of material same quality as harvested after 9 month storage

IBSAL Cost Comparison



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Summary

Photo courtesy of Matt Darr, Iowa State University

Summary

- Existing forage and silage systems not likely to meet cost limits
- Optimum systems will be crop, location and conversion process specific
- Second generation logistics systems under development and show promise

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