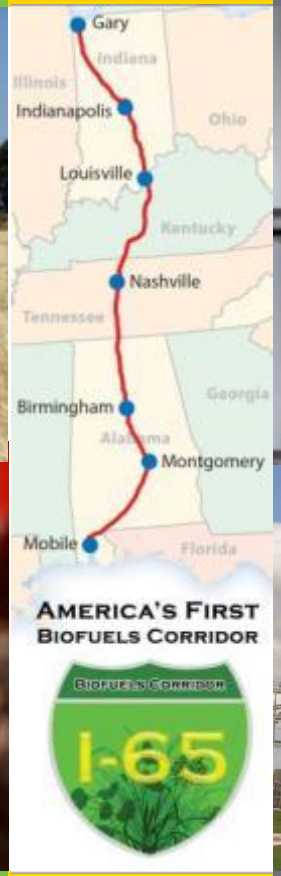
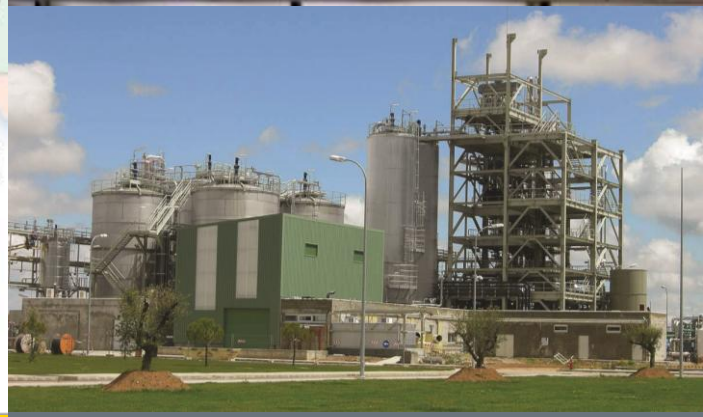
Biomass 2012

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





Raw Biomass to Commodity Feedstocks

July 10 2012

Richard Hess

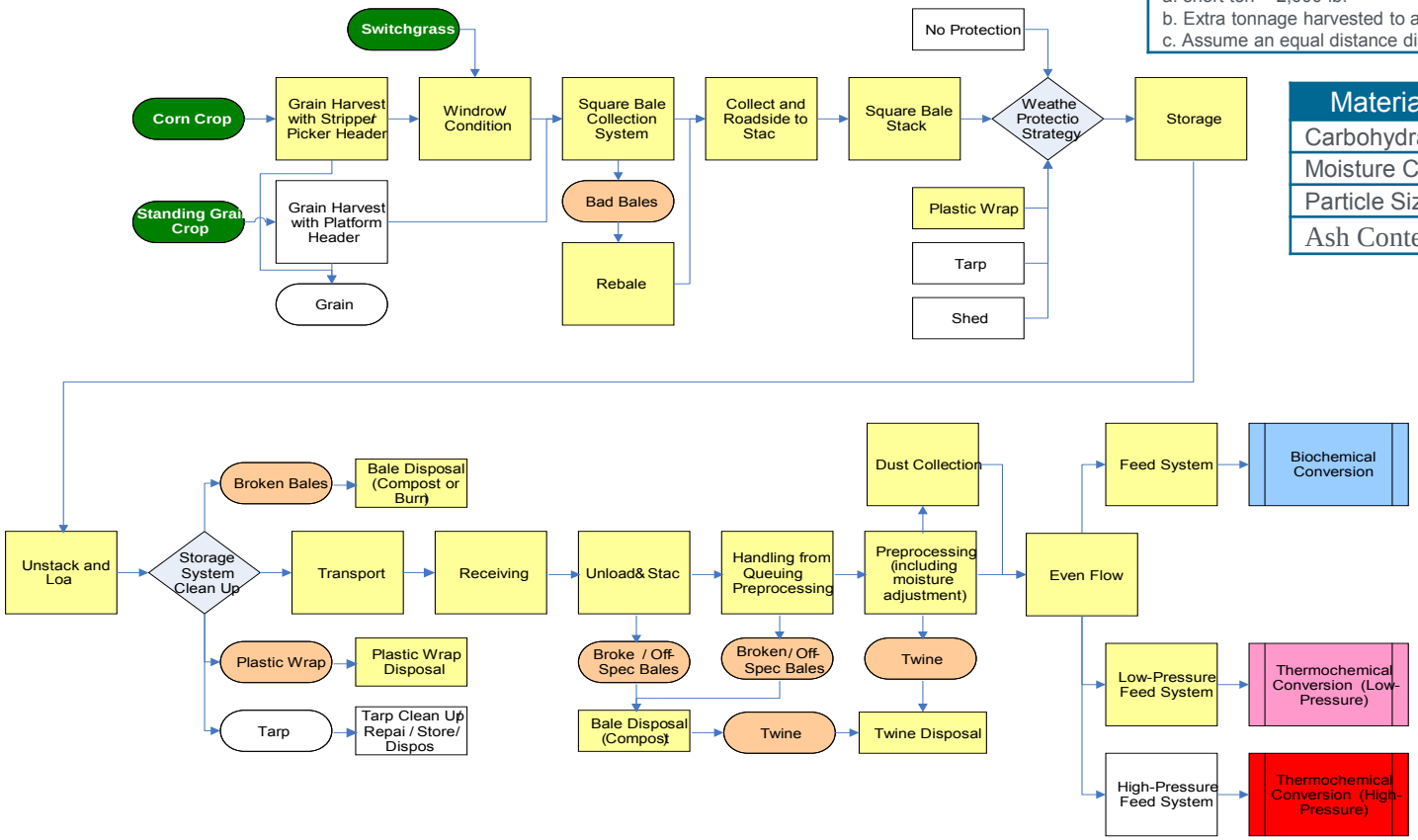
Idaho National Laboratory

2012 Herbaceous (Corn Stover) Feedstock Design

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Logistic Requirements	Corn Stover
Plant Operation Size (delivered tons[a])	800,000 DM ton/yr
Feedstock Harvested Annually[b]	868,600 DM ton
Acres Harvested Annually	527,000
Participating Acres	50%
Acres Available for Contract	1,054,000
Cultivated Acres	2,107,000
Feedstock Draw Radius[c]	45.8 miles

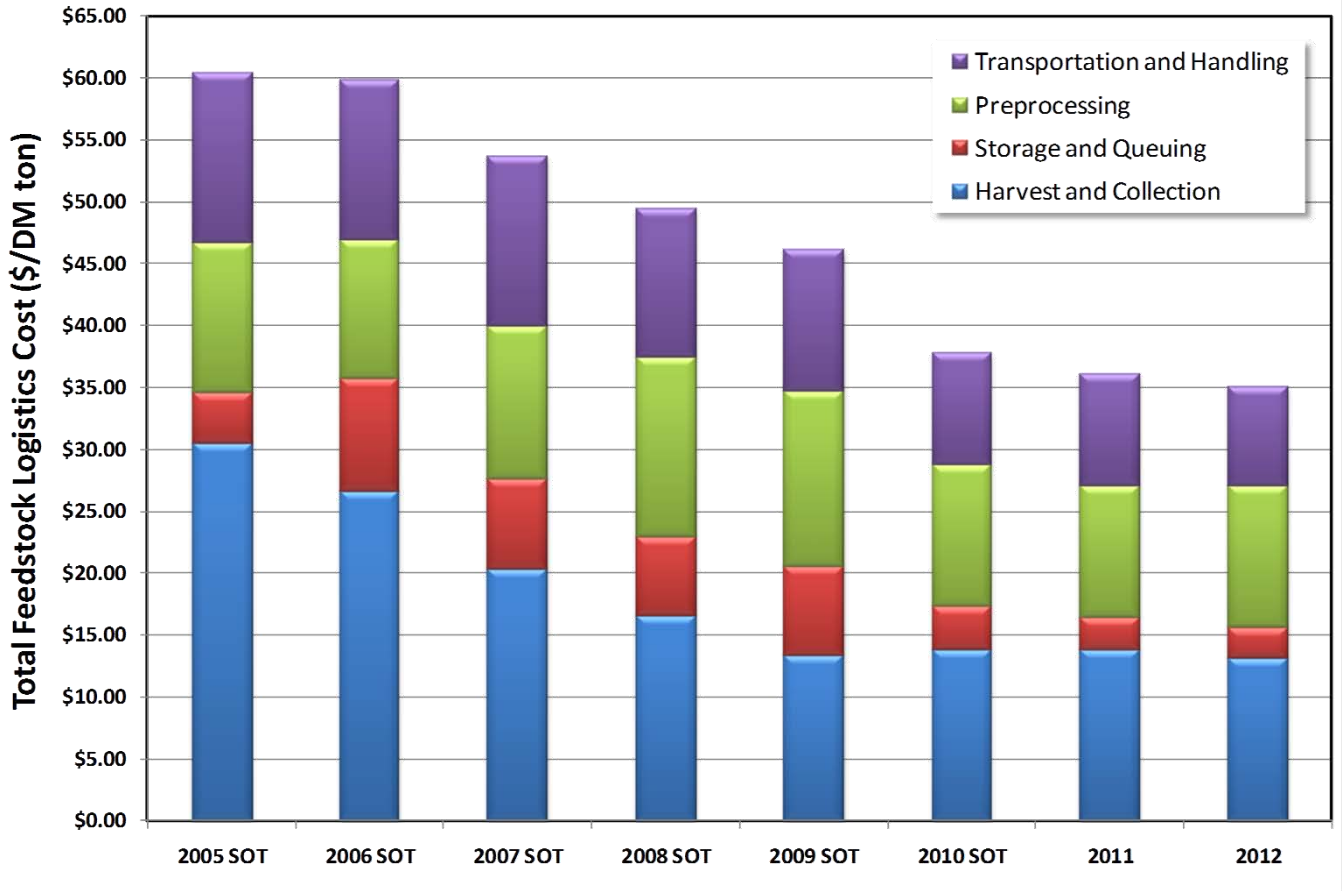
a. short ton = 2,000 lb.
b. Extra tonnage harvested to account for supply system losses.
c. Assume an equal distance distribution of acres throughout the draw radius.



Material Specifications	Corn Stover
Carbohydrate Content	60%
Moisture Content	12%
Particle Size	¼ minus
Ash Content	5-6%

Sustainability Limiting Factors
Soil Organic Carbon
Wind/Water Erosion
Plant Nutrient Balance
Soil/Water Temperature Dynamics
Soil Compaction
Off-Site Environmental Impacts

Feedstock Logistics Cost Improvement Pathway (2007 $)



Transportation/Handling – Indirect gains due to improved bale density and reduced losses (shrink)

Preprocessing – direct improvements in grinder efficiency and capacity

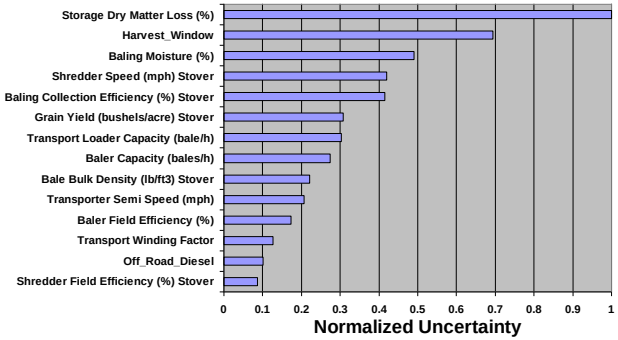
Storage/Queuing – Lower cost storage methods, and reduce uncertainty of storage losses (e.g., preserve the 60% carbohydrate target)

Harvest/Collection – Improved Harvest/collection efficiency (i.e., a yield component) while not violating sustainability limits, and biomass quality (namely ash) targets

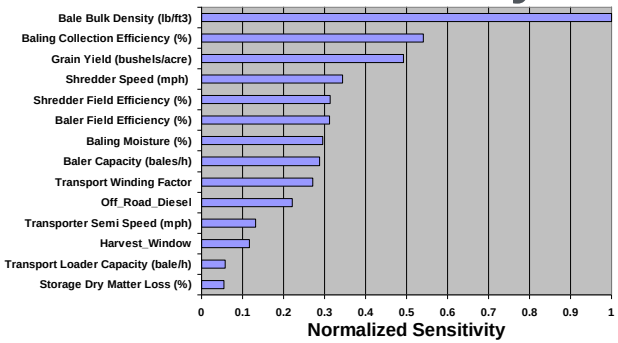
Feedstock Logistics Factors

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

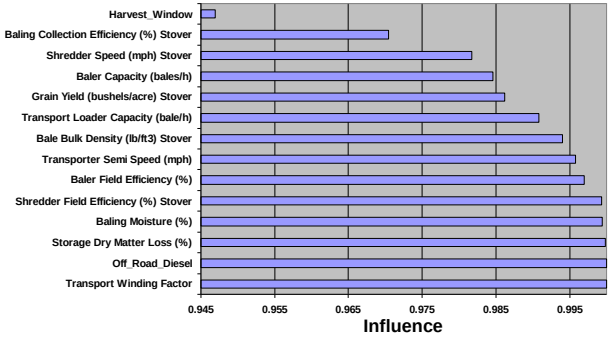
Uncertainty



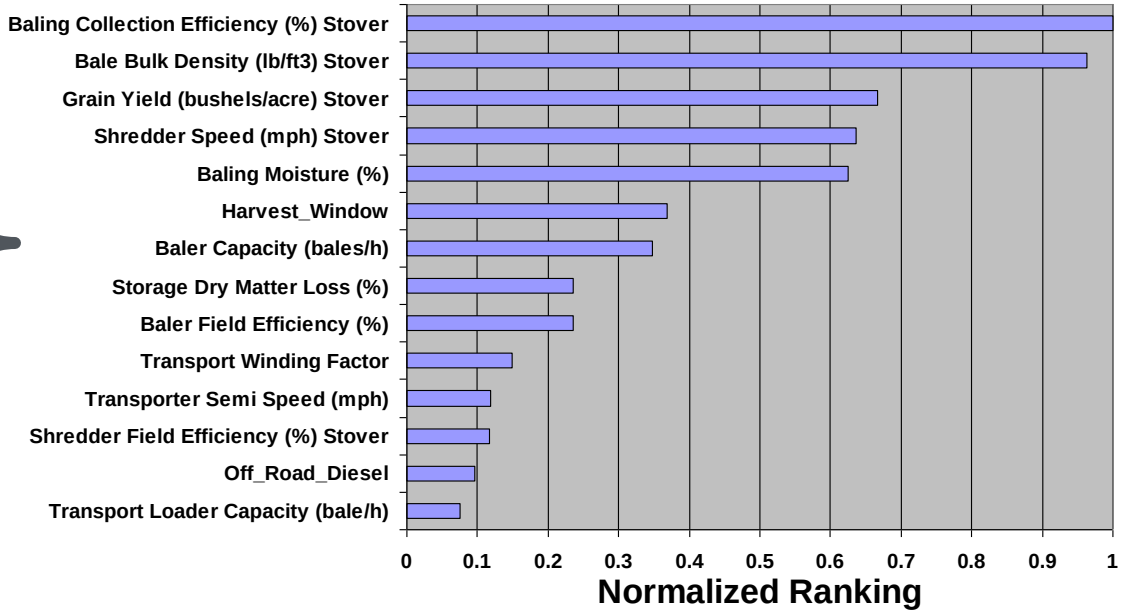
Sensitivity



Influence



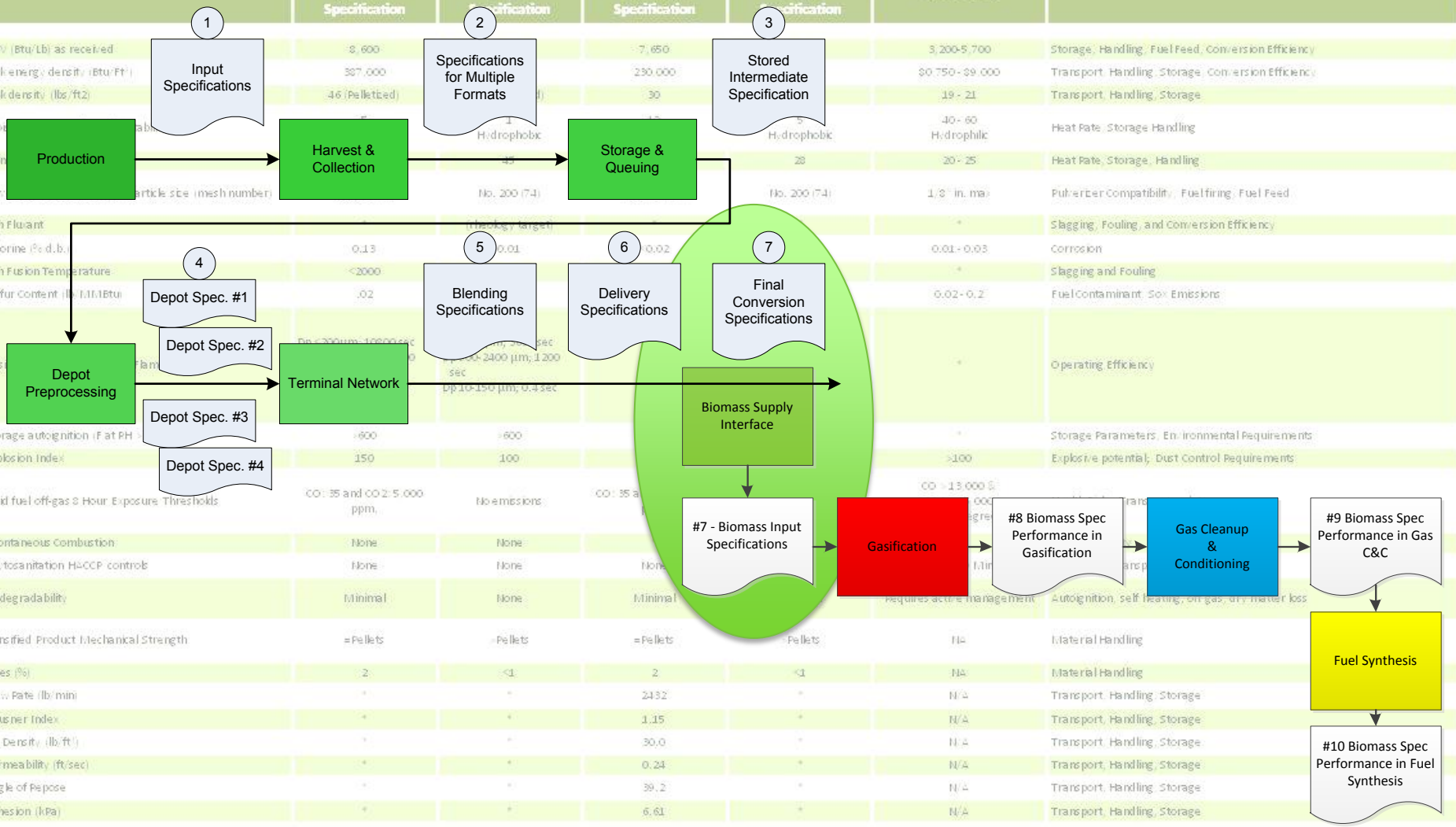
$$\text{Rank} = \frac{\text{Uncertainty x Sensitivity}}{\text{Influence}}$$



Development and Characterization of Process Intermediates

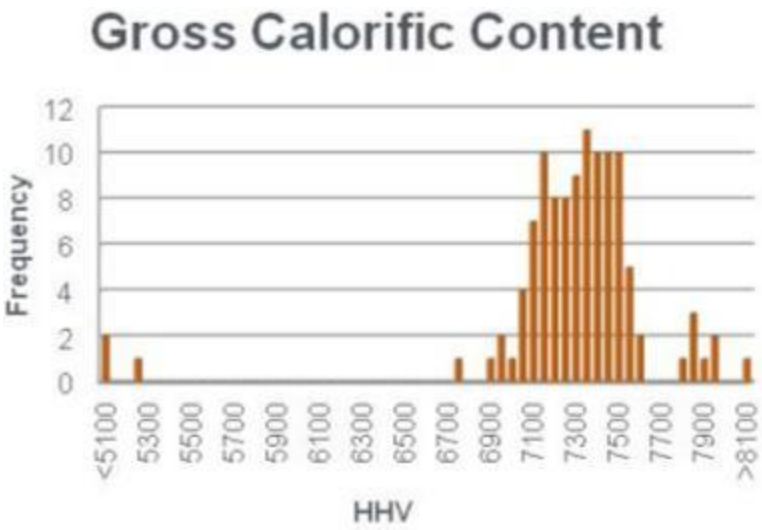
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

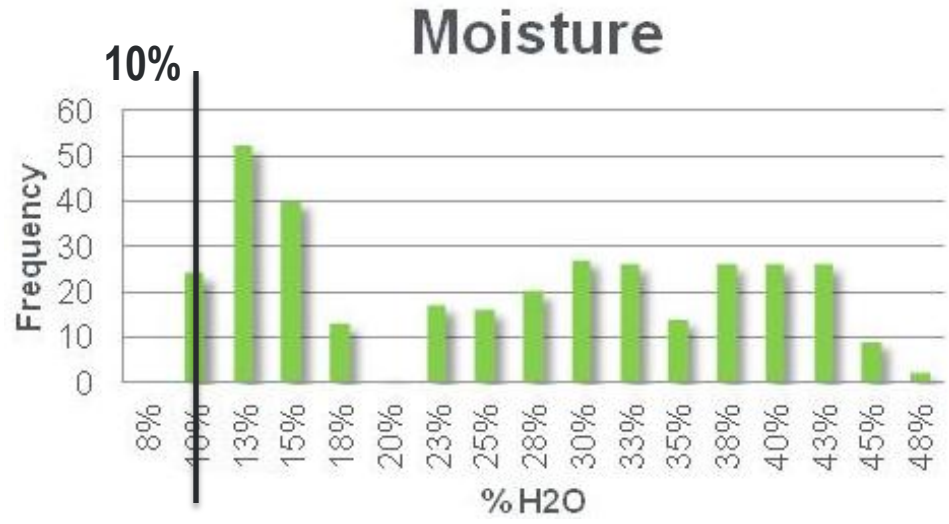
Gasification Feedstock Specifications	Advanced Material (Thermally Treated)		Mechanically Densified (Pelletized or Similar)		For Comparison	Plant Operations Impacts
	Minimum Specification	Target Specification	Minimum Specification	Target Specification	Green Wood	
HHV (Btu/Lb) as received	8,600		7,650		3,200-5,700	Storage, Handling, Fuel Feed, Conversion Efficiency
Bulk energy density (Btu/ft³)	387,000		230,000		$0.750-$9,000	Transport, Handling, Storage, Conversion Efficiency
Bulk density (lbs/ft2)	46 (Pelletized)		30		19 - 21	Transport, Handling, Storage
Moisture		1 Hydrophobic		5 Hydrophobic	40 - 60 Hydrophilic	Heat Rate, Storage Handling
Grind		45		28	20 - 25	Heat Rate, Storage, Handling
Pulverizer Particle size (mesh number)		No. 200 (74)		No. 200 (74)	1/8" in. max	Pulverizer Compatibility, Fuel firing, Fuel Feed
Ash Fluxant		(technology target)				Slagging, Fouling, and Conversion Efficiency
Chlorine (% d.b.)	0.13	0.01	0.02		0.01 - 0.03	Corrosion
Ash Fusion Temperature	<2000					Slagging and Fouling
Sulfur Content (lb/MMBtu)	.02				0.02 - 0.2	Fuel Contaminant, Sox Emissions
Gasifiability		Dp < 200µm; 100000 sec		Dp < 2400 µm; 1200 sec		Operating Efficiency
Storage autoignition (F at RH >)	>600	>600				Storage Parameters, Environmental Requirements
Explosion Index	150	100			>100	Explosive potential; Dust Control Requirements
Solid fuel off-gas 8 Hour Exposure Thresholds	CO: 35 and CO2: 5,000 ppm,	No emissions	CO: 35 a		CO: >13,000 S	
Spontaneous Combustion	None	None				
Phytosanitation HACCP controls	None	None	None			
Biodegradability	Minimal	None	Minimal		Requires active management	Autoignition, self heating, off gas, dry matter loss
Densified Product Mechanical Strength	=Pellets	=Pellets	=Pellets	=Pellets	NA	Material Handling
Fines (%)	2	<1	2	<1	NA	Material Handling
Flow Rate (lb/min)	*	*	2432	*	N/A	Transport, Handling, Storage
Hausner Index	*	*	1.15	*	N/A	Transport, Handling, Storage
Bin Density (lb/ft³)	*	*	30.0	*	N/A	Transport, Handling, Storage
Permeability (ft/sec)	*	*	0.24	*	N/A	Transport, Handling, Storage
Angle of Repose	*	*	39.2	*	N/A	Transport, Handling, Storage
Cohesion (kPa)	*	*	6.61	*	N/A	Transport, Handling, Storage

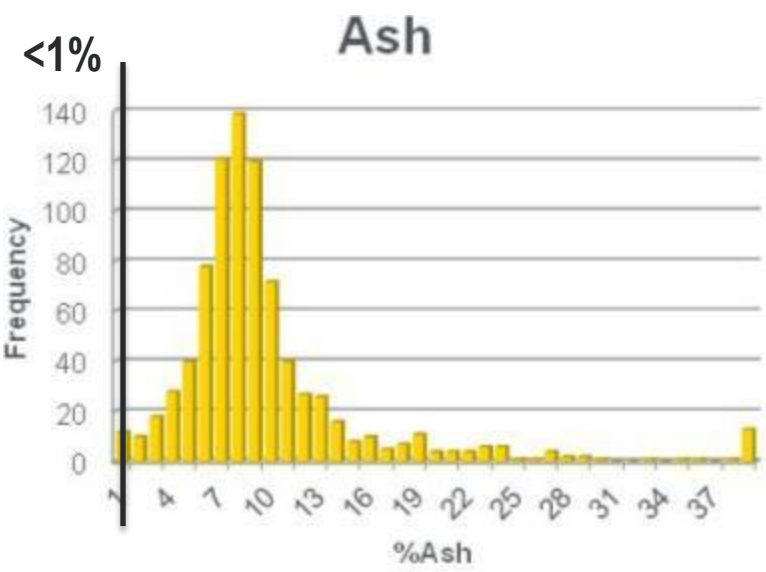


Thermochem Quality Specs

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





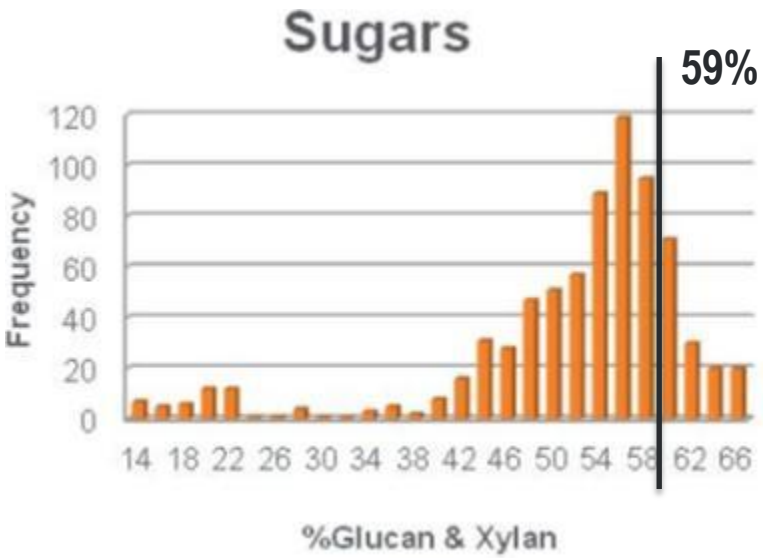


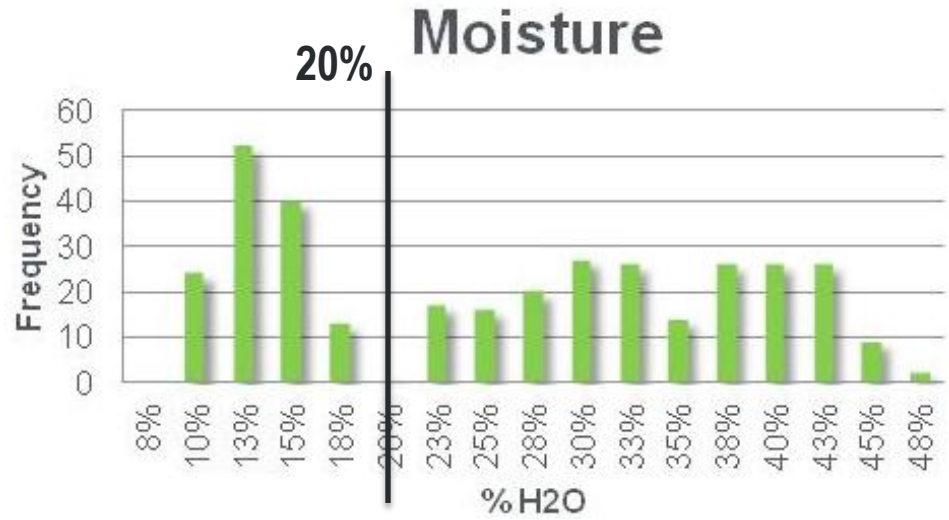
Particle Size & Distribution

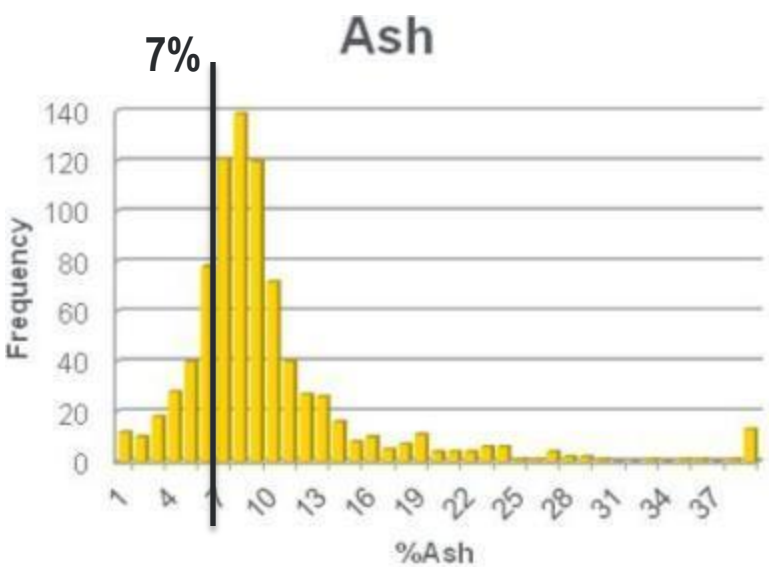
- **2-6 mm**

Uncontrolled Variability Costs Money (e.g., Biochem Quality Specifications)

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy







Particle Size & Distribution

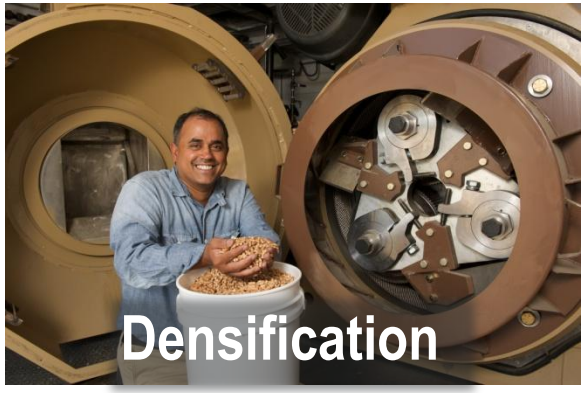
- DOE Design: ¾-in. minus
- IBR: 2-in. minus
- AFEX: ¼-in. minus, narrow PSD

Feedstock R&D Elements to Address Biomass Compositional Uncertainty

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Raw Biomass Development and Best Management Practices

Preprocessing Raw Biomass to Feedstocks Specs



Harvest and Collection Efficiency Improvements

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Start: 43% Harvest/Collection Efficiency
- Current: 75% Harvest Collection Efficiency
- Assumptions: Biomass <20% moisture, Bale Bulk Density 12 lbs/ft^3
- Successes:
  - OEMs have Improved Machine Performance
  - Residue Removal Tool:
    - Quantify multi-factor sustainability limits
    - Increase removal rate as guided by sustainable residue removal plans
  - Mitigate soil contamination associated with increasing collection efficiencies, based on:
    - Residue type and fraction
    - Soil type
    - Target removal rate
  - Improved procedures for bale sampling

Harvest/Collection Efficiency – the ratio of biomass collected to the amount available in the field

Collection Efficiency – A Tradeoff with Quality

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- As material collection rates increase, the fraction of entrained soil increases as well
- The ash content of a bale depends largely on collection technique and field conditions.
- Conventional windrowing and baling of biomass does not actively seek to minimize ash.

Best Management Practices: Ash Reduction

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Windrowing Treatment	Bale Comp.	Moisture Range	Ash (%, dry)	Cost ($/dry ton)
Wheel Rake	MOC	lower	10-17	$4.50 - $8.30
Bar Rake	MOC	lower	7-14	$3.10 - $6.60
Flail Shredder	MOC/ Stubble	higher	9-19	$4.00 - $9.50
Single-pass	MOC/Cob	variable	4-12	$1.70-$5.50

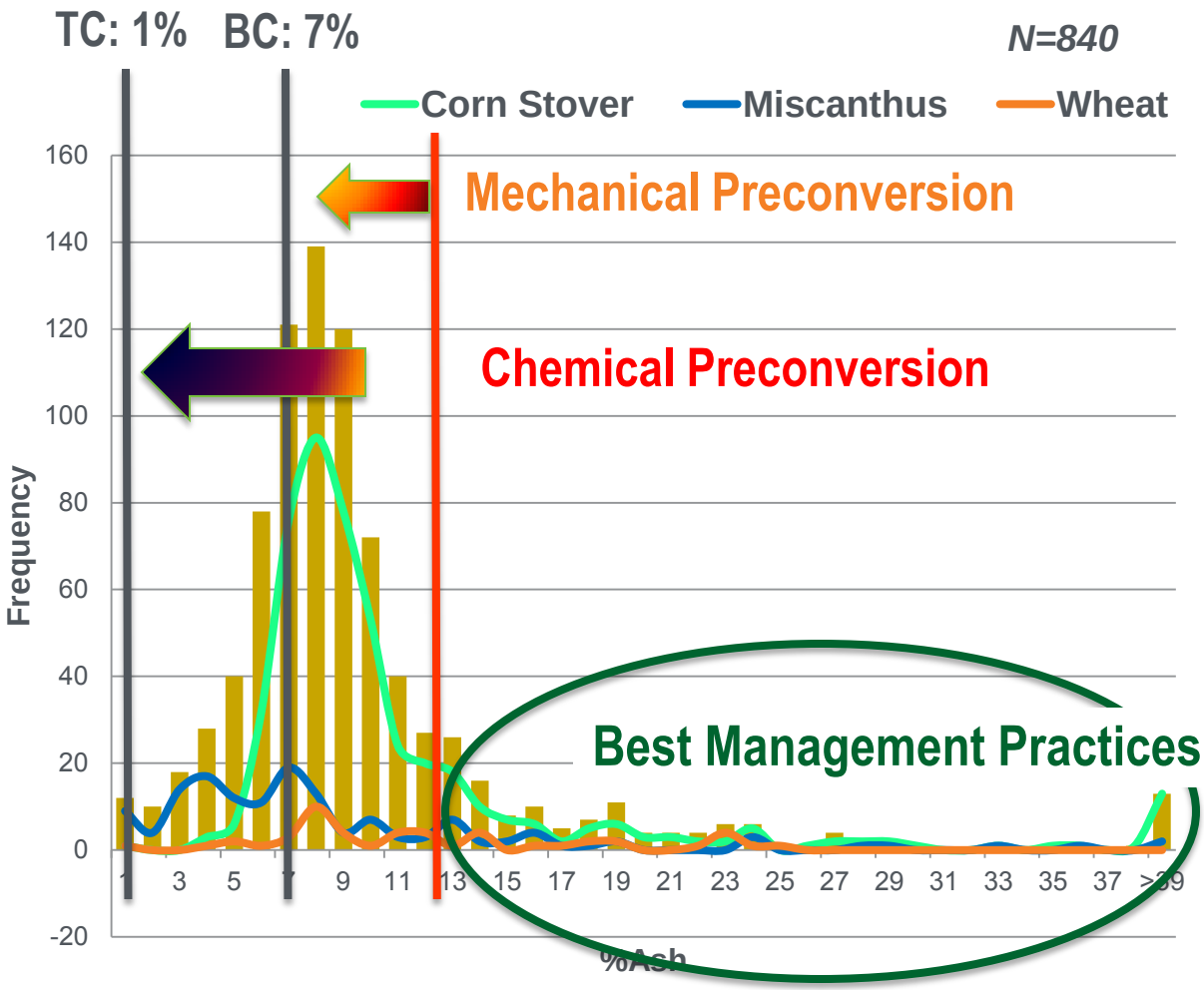
MOC = Material-Other than-Cob (upper stalk, husk, leaf)

Goal: Reduce ash content to physiological levels (5-6 wt%)

Results are highly variable depending on

- Stover fractions
- Removal rate
- Field/soil conditions

Preprocessing to achieve final ash spec



Mechanical Preconversion

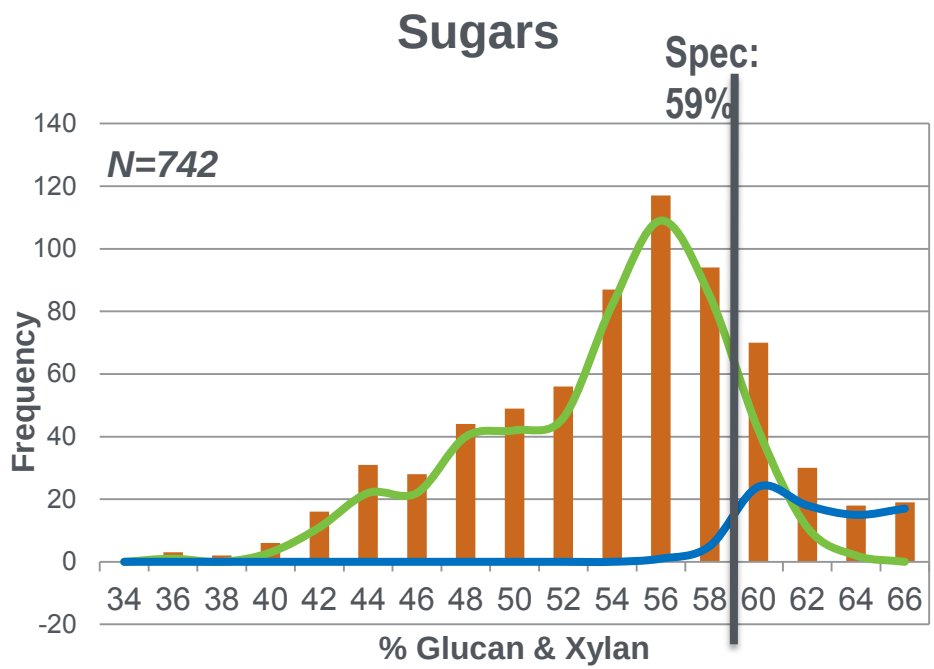
- Removal of non-structural ash (soil)
- Fractionation & separation of high ash anatomical fractions
- Sieving to remove soil

Chemical Preconversion

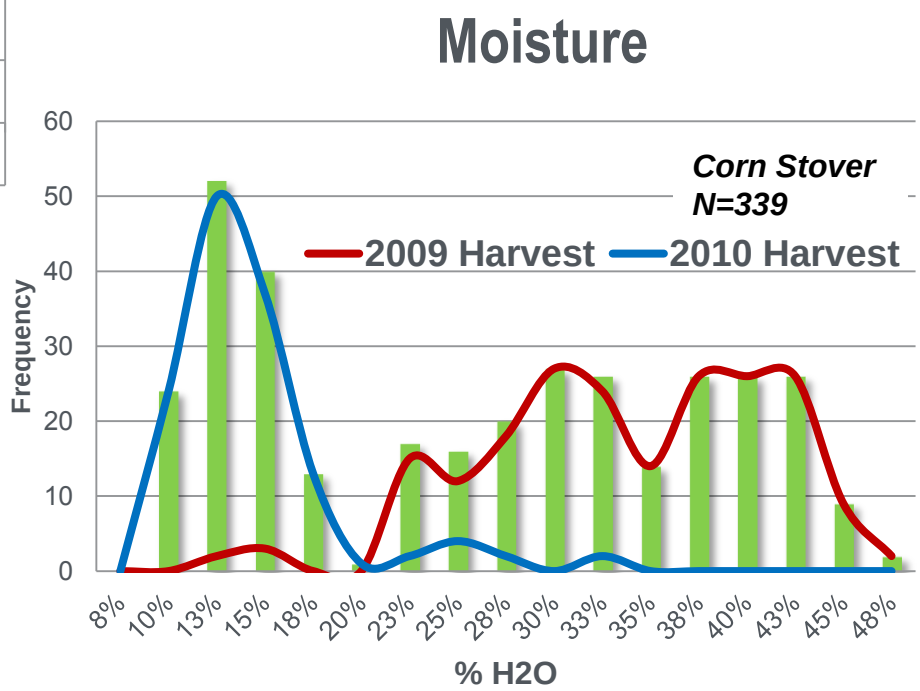
- Removal of structural ash
- Hot water
- Acidic
- Alkaline

Sugar Content in Biomass Sources & Intermediates – Biomass Library Data

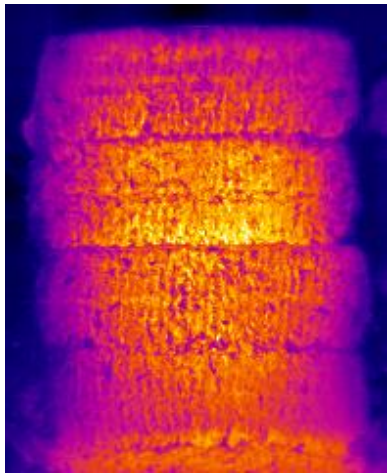
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

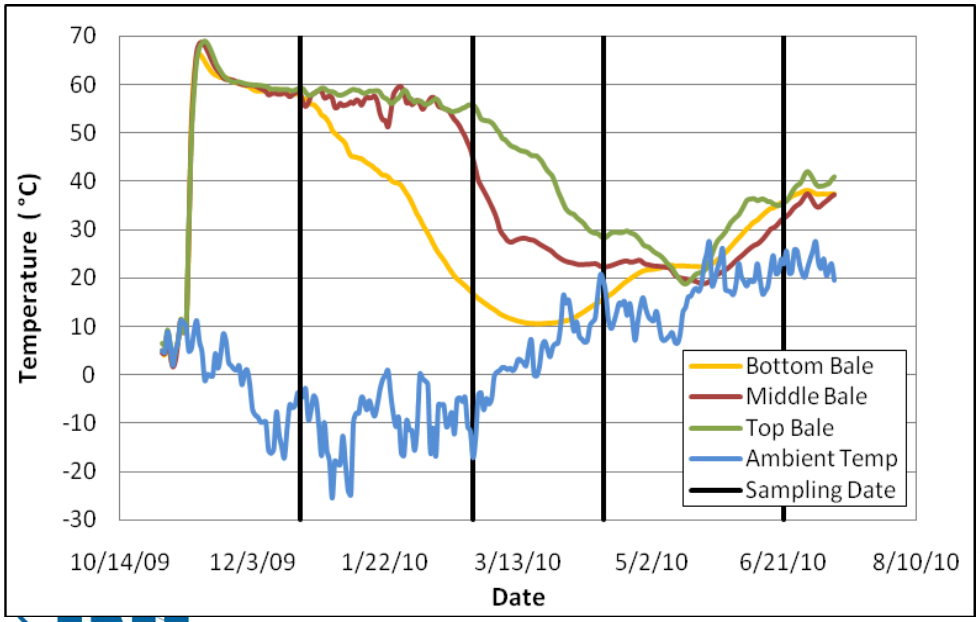


Final sugar content is tightly coupled to the impact of moisture biomass stability



Moisture Management in Wet Storage



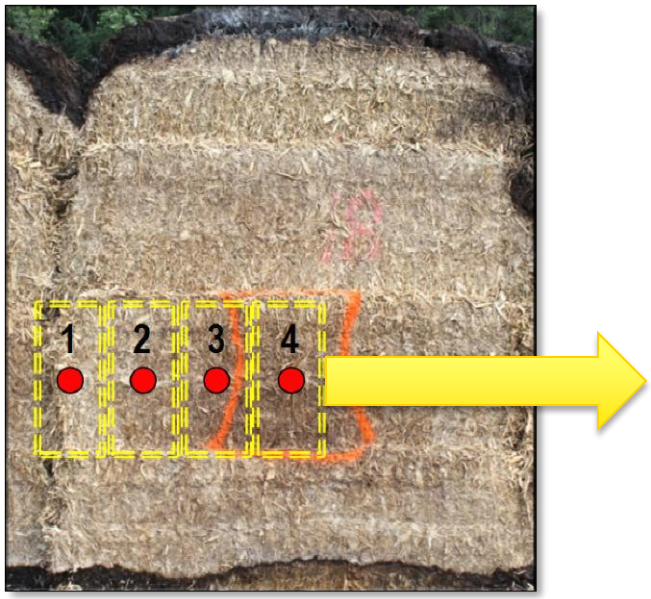


- Conventional approach: ensiling for long-term storage
- BMP approach combines moisture content and time to accommodate baled storage of wet material based upon “shelf-life”—opens door to conventional storage over wider moisture range
- Shelf-life implies temporal stability defined by
  - Extent of degradation
  - Rate of degradation
- Shelf-life influenced by
  - Moisture content
  - Self-heating
  - Stack configuration
  - Environmental factors

Composition and Value

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Extent of loss over time determines value threshold.
  - Structural carbohydrate loss leads to ethanol yield loss.
- Regions that *stay wet* suffer in terms of composition and value.



17 – 24 $ / DMT Difference

	1'	2'	3'	4'	
Initial	Drying Front / Time (9 Months)				
32.1	18.5	13.6	13.0	28.5	*Moisture Content (% wb)*
87	86	89	80	76	*Theoretical EtOH Yield*
$188.00	$185.00	$191.00	$171.00	$164.00	*Theoretical Feedstock Value (EtOH $/DMT)*

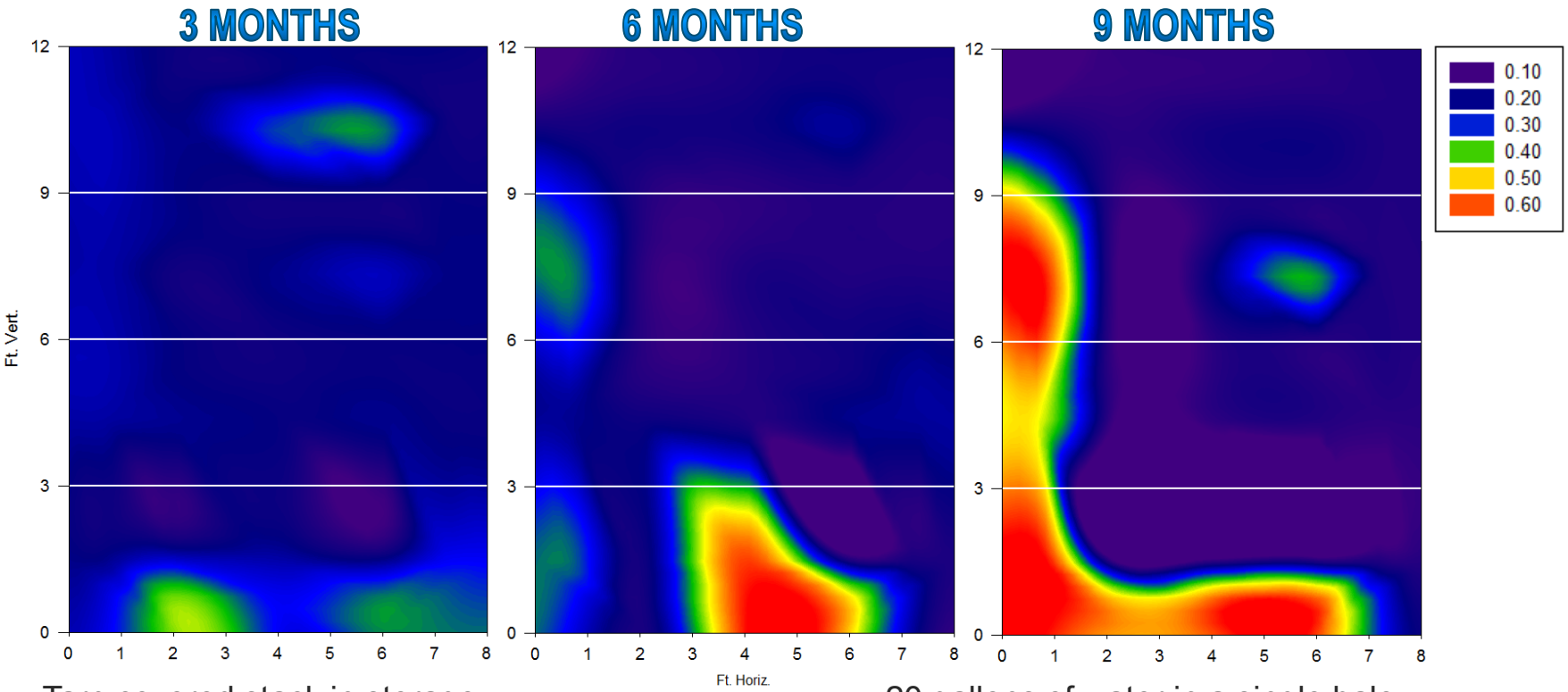
Value indistinguishable from initial material

- Regions that *dry while in storage* retain composition and value.

Moisture Management in Dry Storage

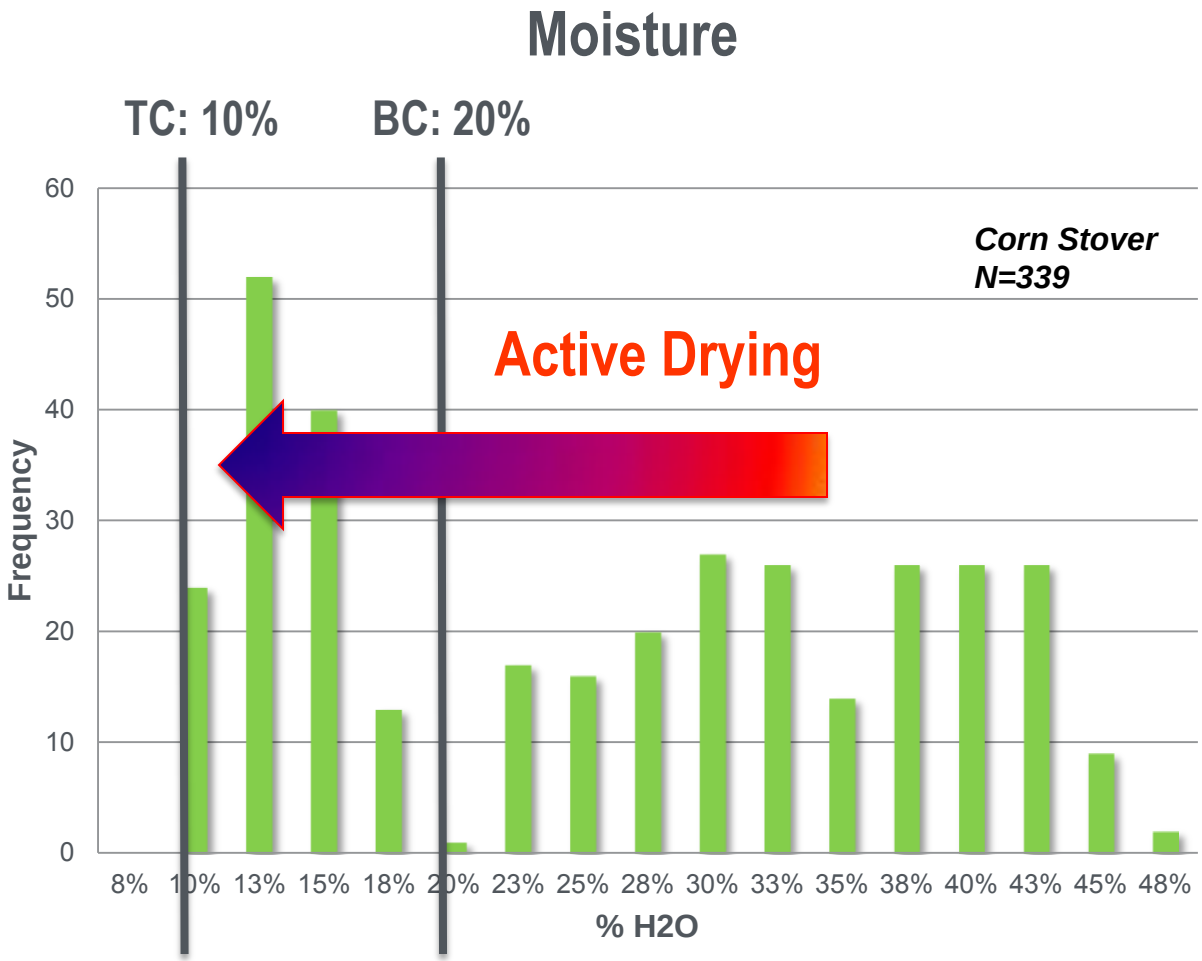
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Conventional approach: <15% moisture content = stable dry storage
- Moisture gain and migration results in significant losses even in materials that enter "dry"
- Moisture management requires a system approach (aggregation of bale properties, stack configuration, and environmental influences)



- Tarp covered stack in storage
- Initial moisture content of 13.8% (wb)
- 20 gallons of water in a single bale
- 80 gallons in a 4-high column

Preprocessing to achieve final moisture spec



Residence time drying using low-grade (waste) heat prior to processing

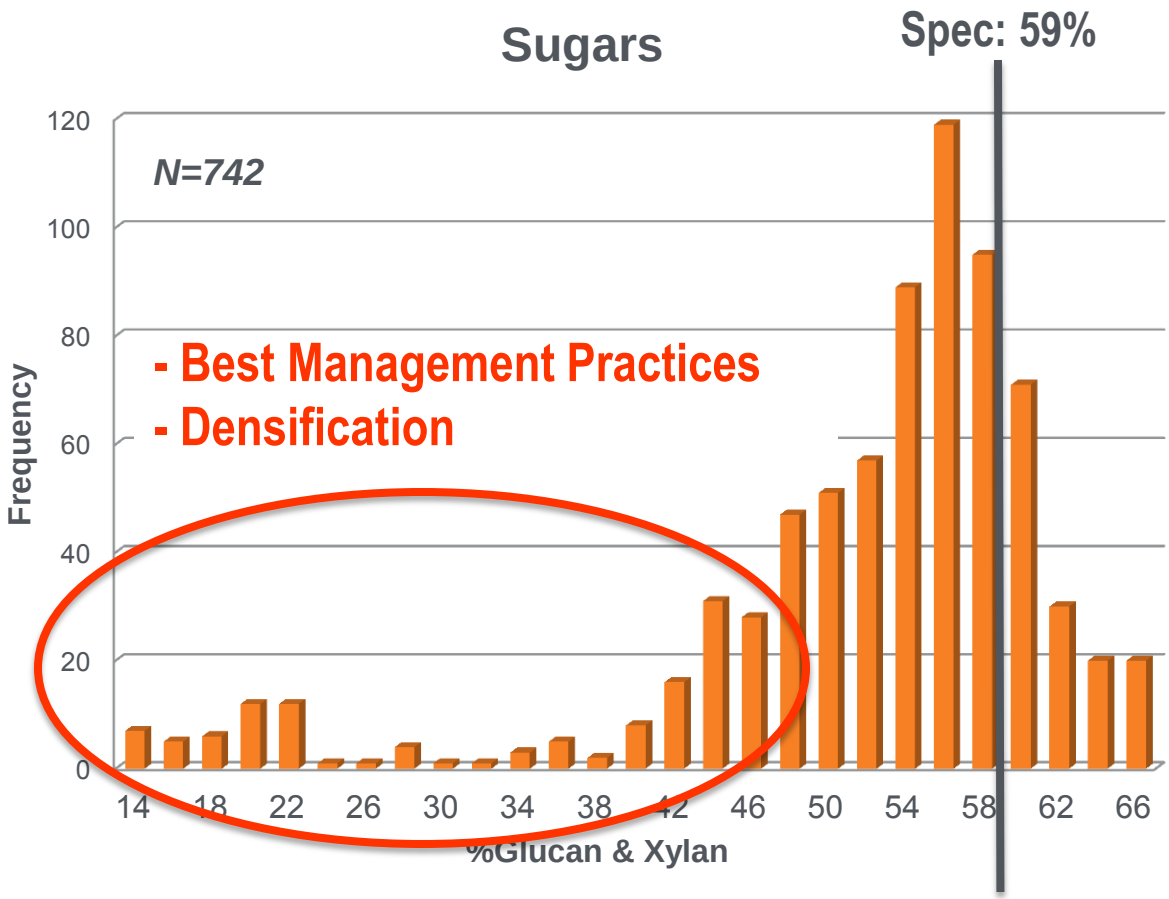
High temp., low residence time drying

Best Management Practices for Sugar Preservation

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BMP: Sugar preservation in storage

Stabilization through densification

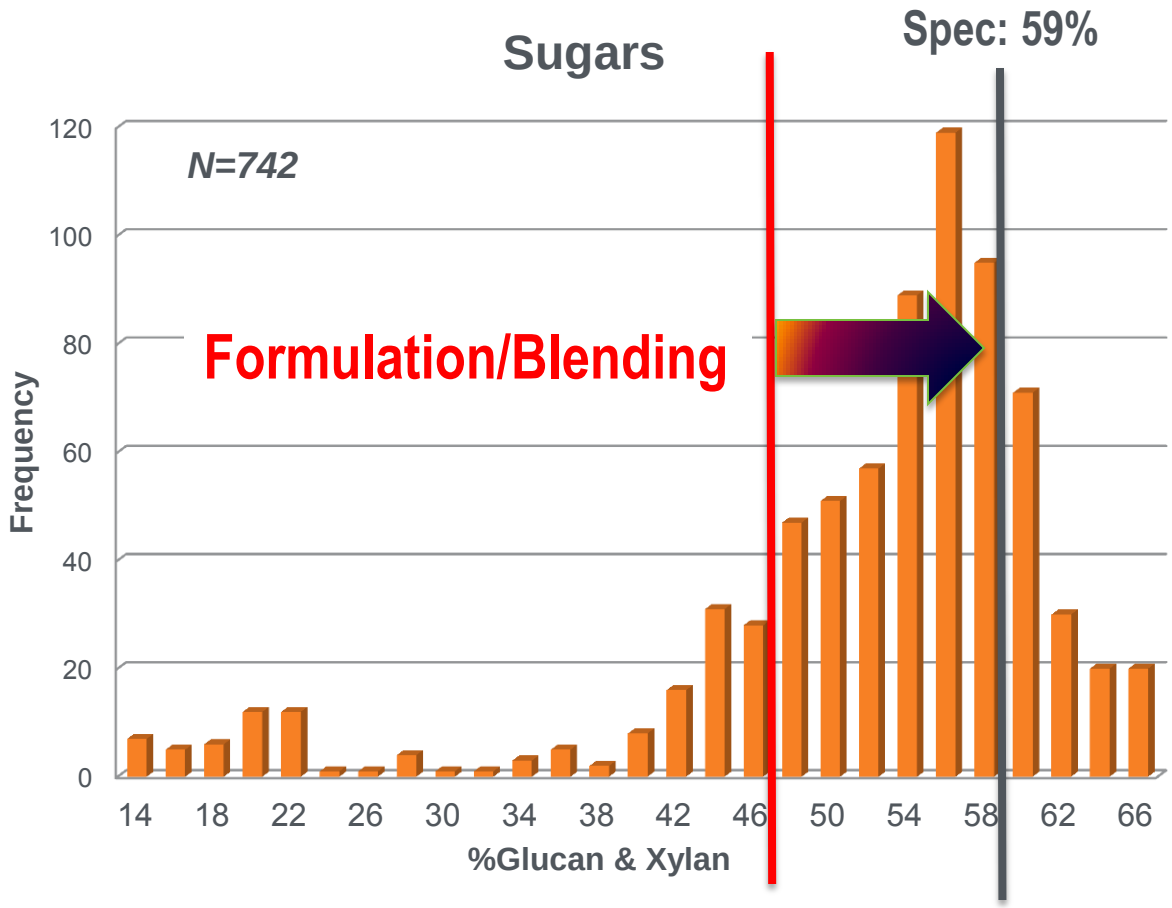


Preprocessing to achieve final sugar spec

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Formulation

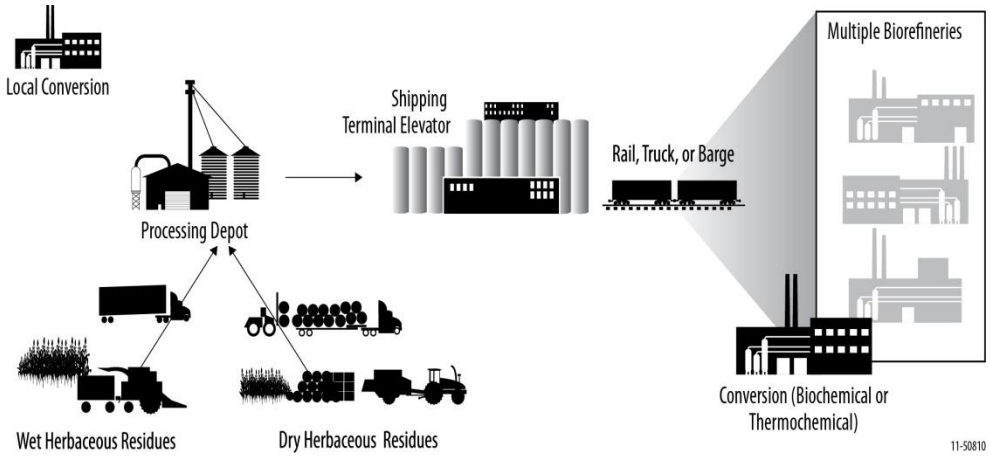
- Aggregation – blending of same biomass type to spec
- Blending – multiple resource types to spec
- Amendment – blend with source of cheap sugars



Feedstock R&D Beyond 2012 – Expands beyond cost to actively manage quality

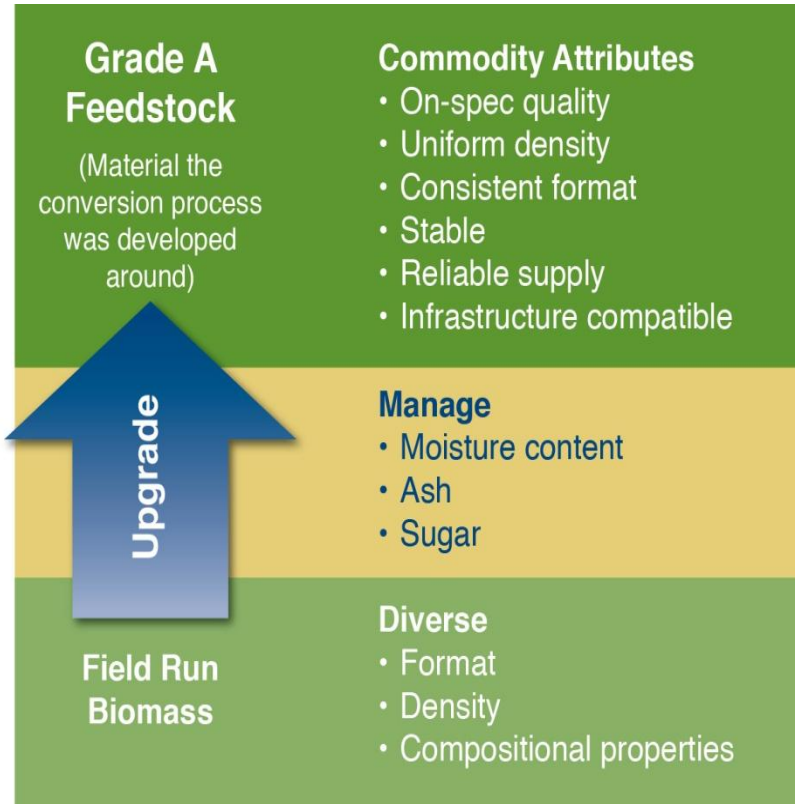
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

1. Density and Stability



1. Infrastructure Compatible (16 lb/ft^3 in field to >48 lb/ft^3 in supply system)
2. Long-term stability in supply system (years, like grain or coal)

2. Conversion (or end use) Performance



(whether solid, pyrolysis oil, or fermentable liquid, all share common concepts, hurdles, and barriers)