U.S. Department of Energy
Energy Efficiency and Renewable Energy

biomass program

Critical Supply Chain Issues: Quality factors, moisture management, and logistics

Biomass Supply Chain & Logistics Update
International Conference on Sorghum for Biofuels

Houston, TX
August 19, 2008

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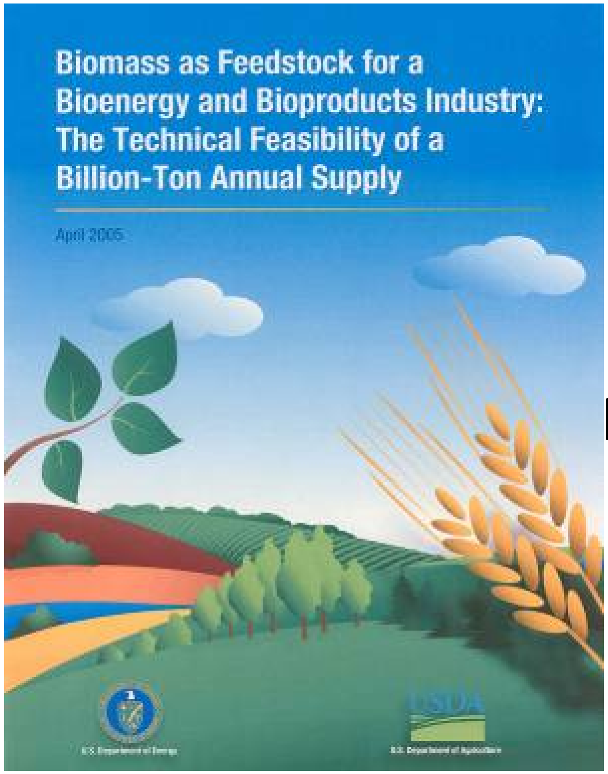
DOE Biorefining Industry 2030 Goals



http://bioenergy.ornl.gov

Displace a significant fraction of gasoline demand
~ 60 billion gallons/year by 2030

~1.3 Billion tons/yr Biomass Potential in the U.S.

Sugar Platform

Syngas Platform

Including Corn Grain, an Estimated 600 – 700 Million Tons of Biomass per Year is Needed for 60 B gal of ethanol.

Trends in Feedstock Supply Logistics

- Connect the diversity of feedstock resources to standardized biorefinery conversion facilities (Biochem and Thermochem)
  - Standardize biomass material attributes (physical properties) and quality specifications
  - Commodity-Scale Lignocellulosic Supply System
- Improve Feedstock Supply System Logistics
  - Engineer (preprocess) biomass materials for more efficient handling/storage
  - Moisture management for stable storage
  - Utilize existing high efficiency solid/liquid handling infrastructure

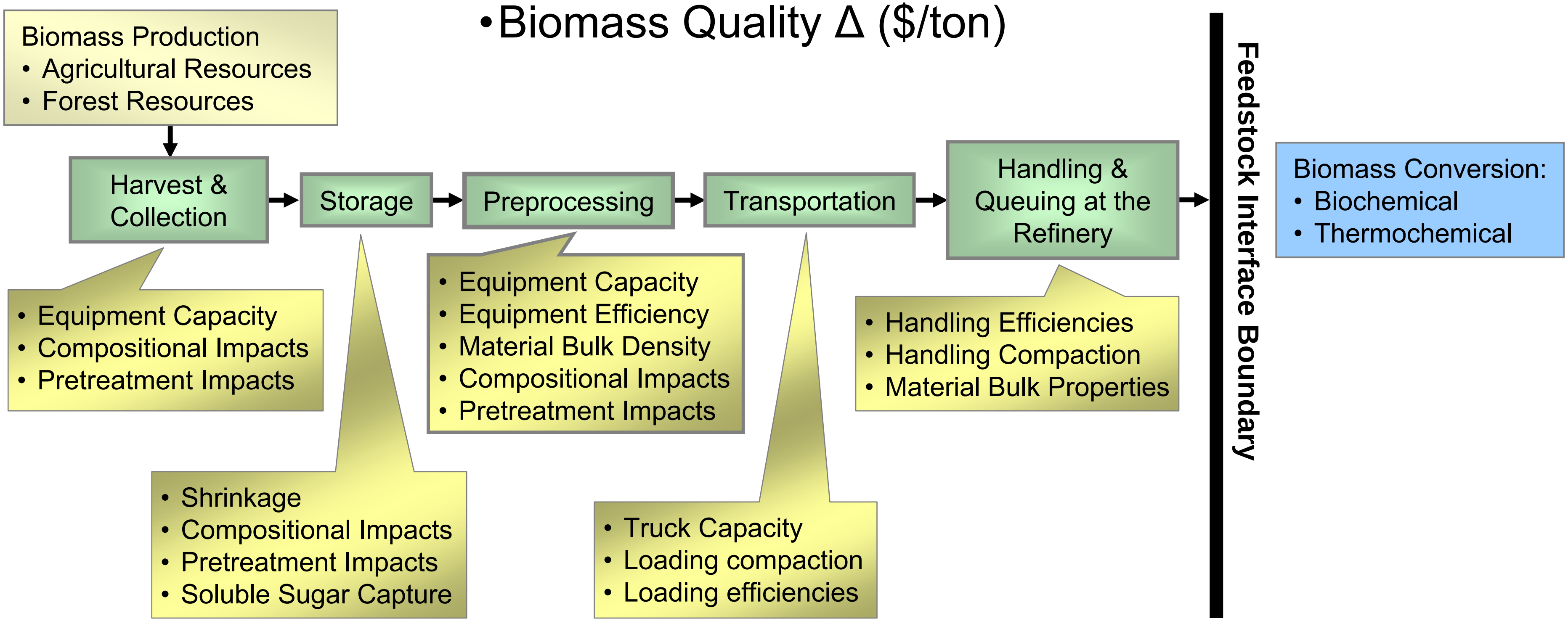
Lignocellulosic Feedstock Types

- Dry Herbaceous – Agriculture Residues/Crops less than 15% moisture
- Wet Herbaceous - Agriculture Residues/Crops greater than ~ 50% moisture
- Energy Crops – Dry and Wet
- Woody – Forest resources and woody energy crops

Supply systems must be tolerant of a diversity of feedstock resources and moistures

Feedstock Supply System Operations

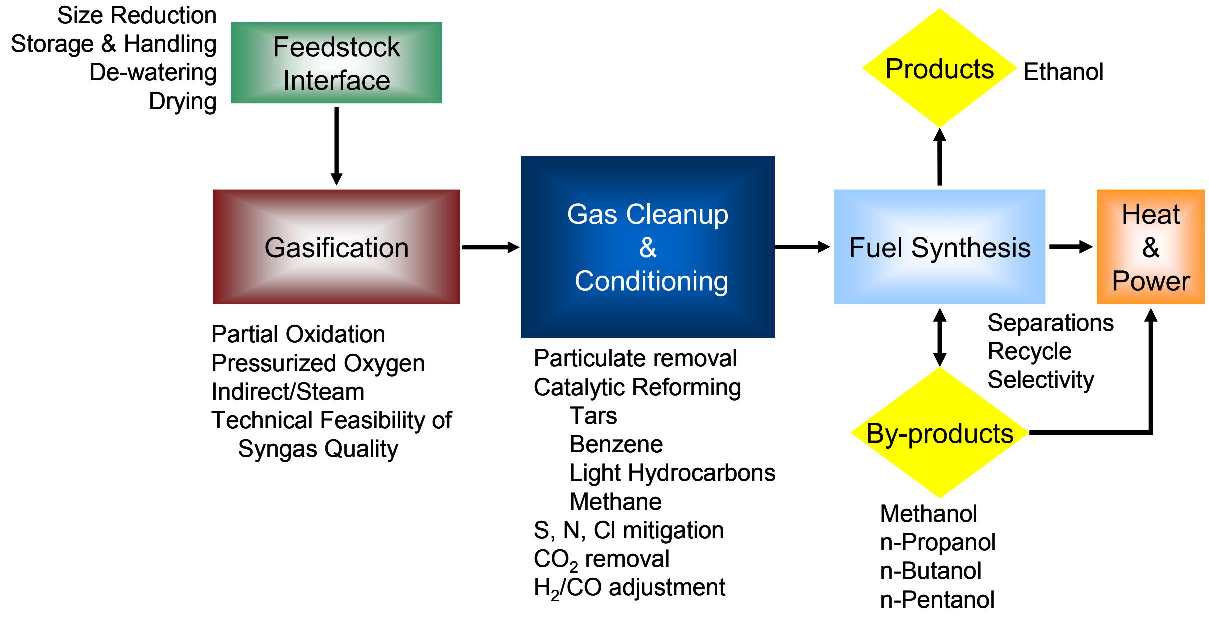
Performance Metrics:
- Efficiency ($/hr)
- Equipment Capacity (ton/hr)
- Biomass Quality Δ ($/ton)



Feedstock – Thermochem Interface

Critical Biomass Attributes that Impact Cost and Performance:

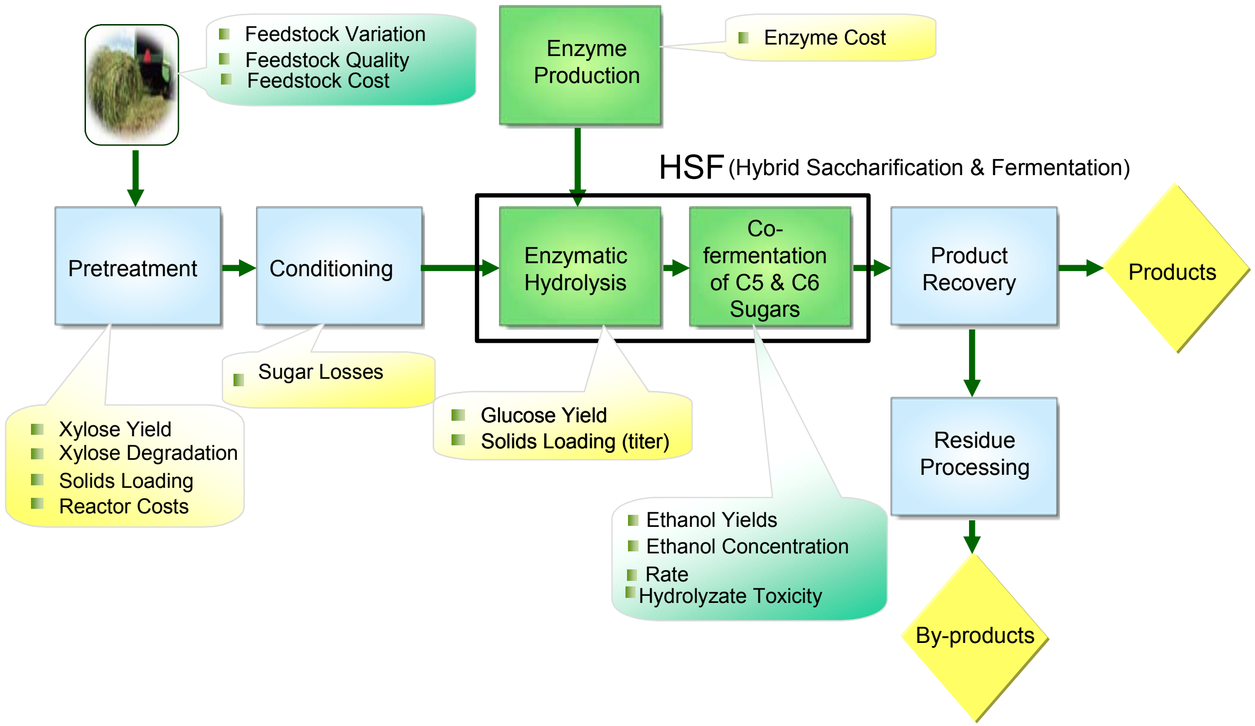
- Material Particle Size (including distribution)
- BTU Content
- Flow Properties
- Moisture Content
- Bulk Density
- Ash Content
- Ash Chemistry
- Chlorine Content
- Alkali Content



Feedstock – Biochemical Interface

Critical Biomass Attributes that Impact Cost and Performance:

- Structural Sugar Content
- Recalcitrance
- Ash Content
- Bulk Density
- Flow Properties
- Moisture Content



Structural Sugar Impacts & Mitigation

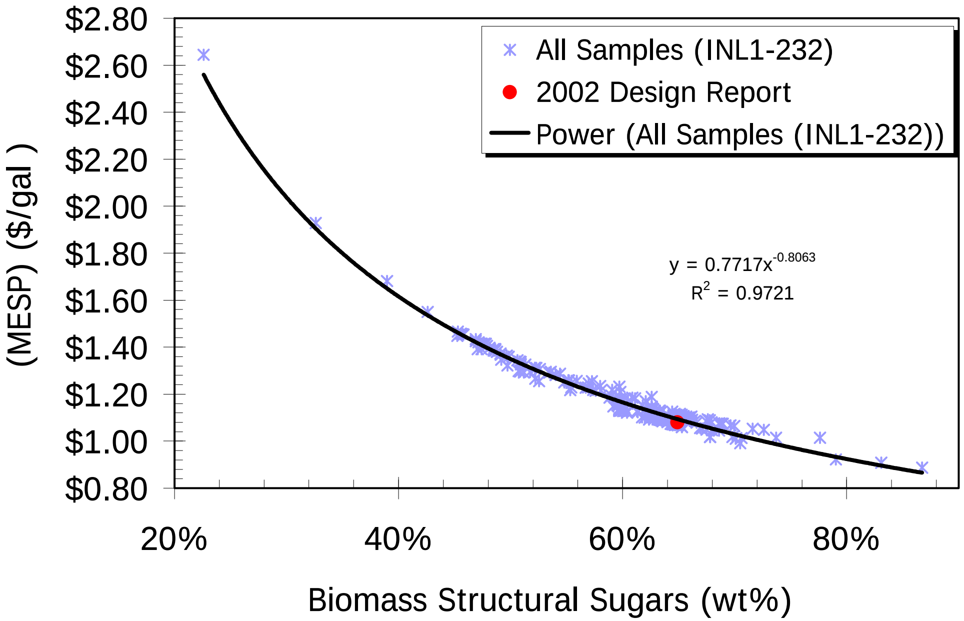
Production, Supply Chain

Relatively insensitive to [structural sugars]

Mitigation/Optimization

•Geography
•Genetics
•Agronomics
•Harvest
•Storage
•Preprocessing

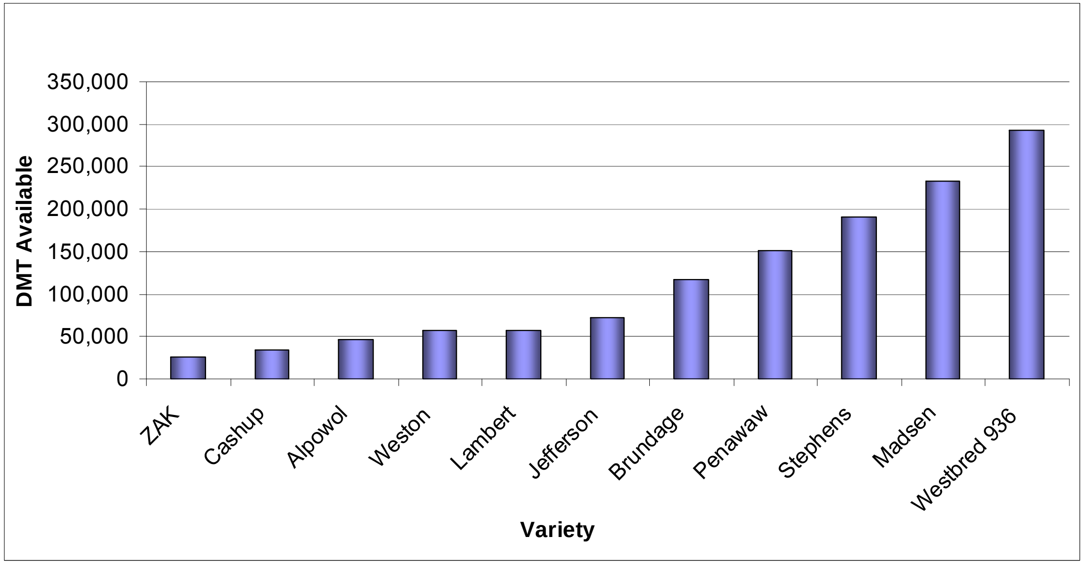
Biorefinery



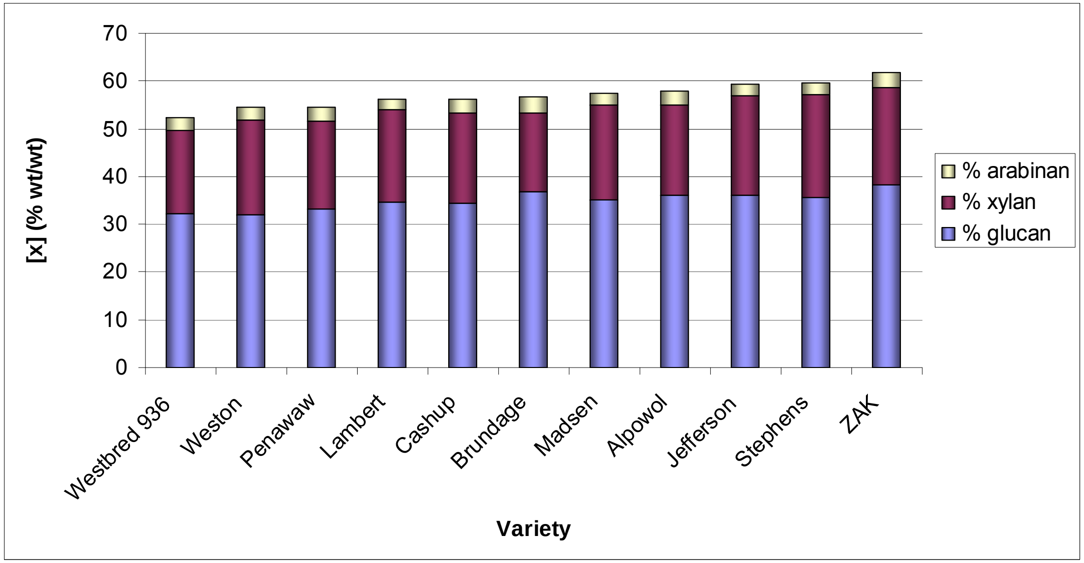
(NREL ASPEN results for 232 INL samples)

Example: Idaho Wheat Straw

Feedstock Availability:



Feedstock Composition:



Nearly a quality/tonnage reversal

Wheat Stover Compositions per Harvest Scenario

Harvest Type	2-Pass	Single Pass[a]	Single Pass with Separation	Single Pass with Separation
Scenario	Bale	Total Wheat Stover	Straw Fraction	Chaff and Leaf Fractions
Mass Fraction of Available Tonnage in the Field (%wt/wt)[b]	27.4	54.7	28.6	26.1
Glucan (%wt/wt)	39.6	37.1	41.3	32.4
Xylan (%wt/wt)	24.9	22.8	22.3	23.4
Galactan (%wt/wt)	1.5	0.9	0.8	1.1
Arabinan (%wt/wt)	3.6	2.0	1.9	2.2
Mannan (%wt/wt)	0	0.6	0.4	0.8
Acid Insoluble Ash (%wt/wt)	10.2	7.7	4.5	11.2
Lignin (%wt/wt)	11.5	17.5	17.9	17.0

a. Calculated based on mass fractions and compositional results of chaff and straw
b. Assuming a ratio of 46% straw and 42% chaff available in intact plants, and a 54.7% removal rate during harvest (INL unpublished data)

Note the large differences in sugars and ash as impacted by harvest

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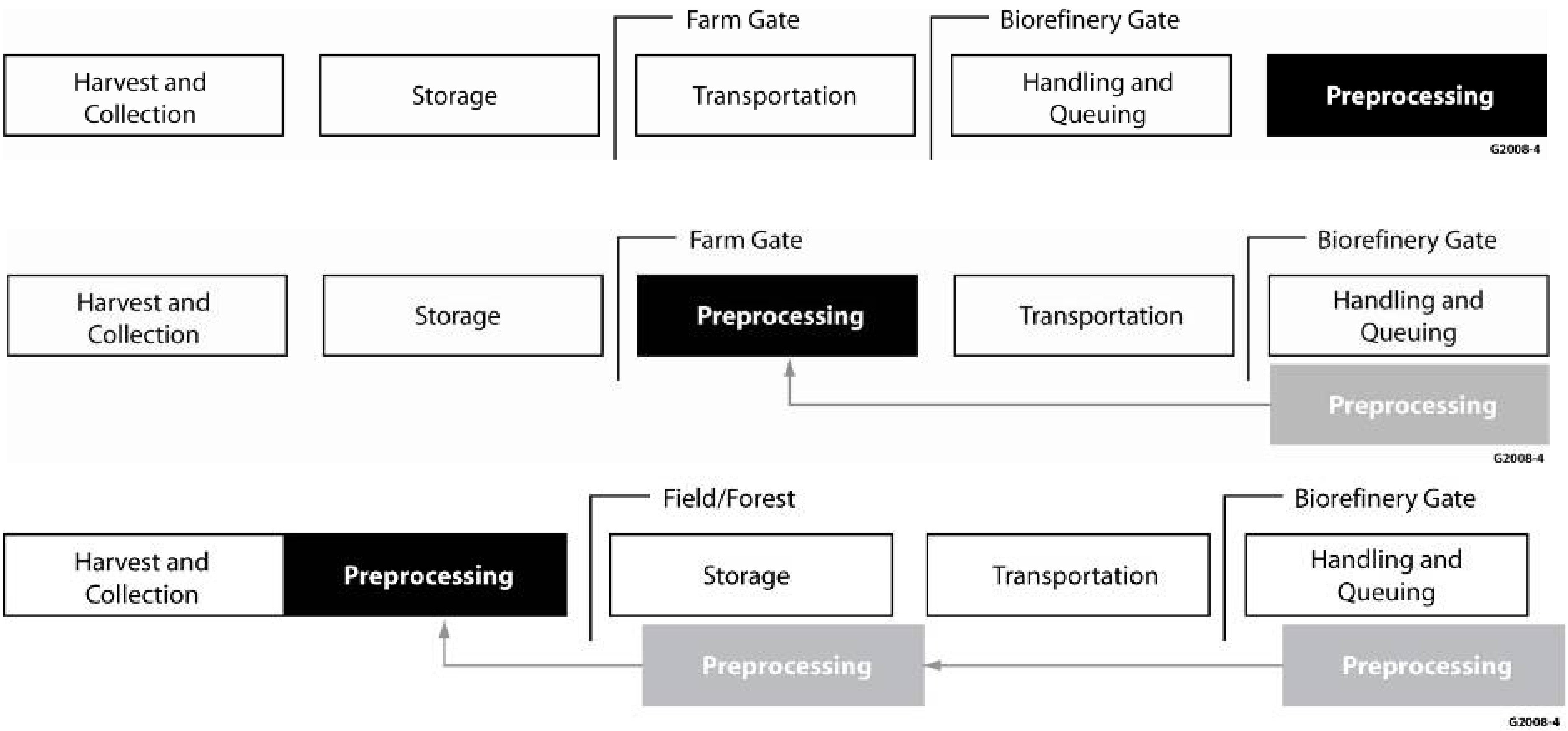
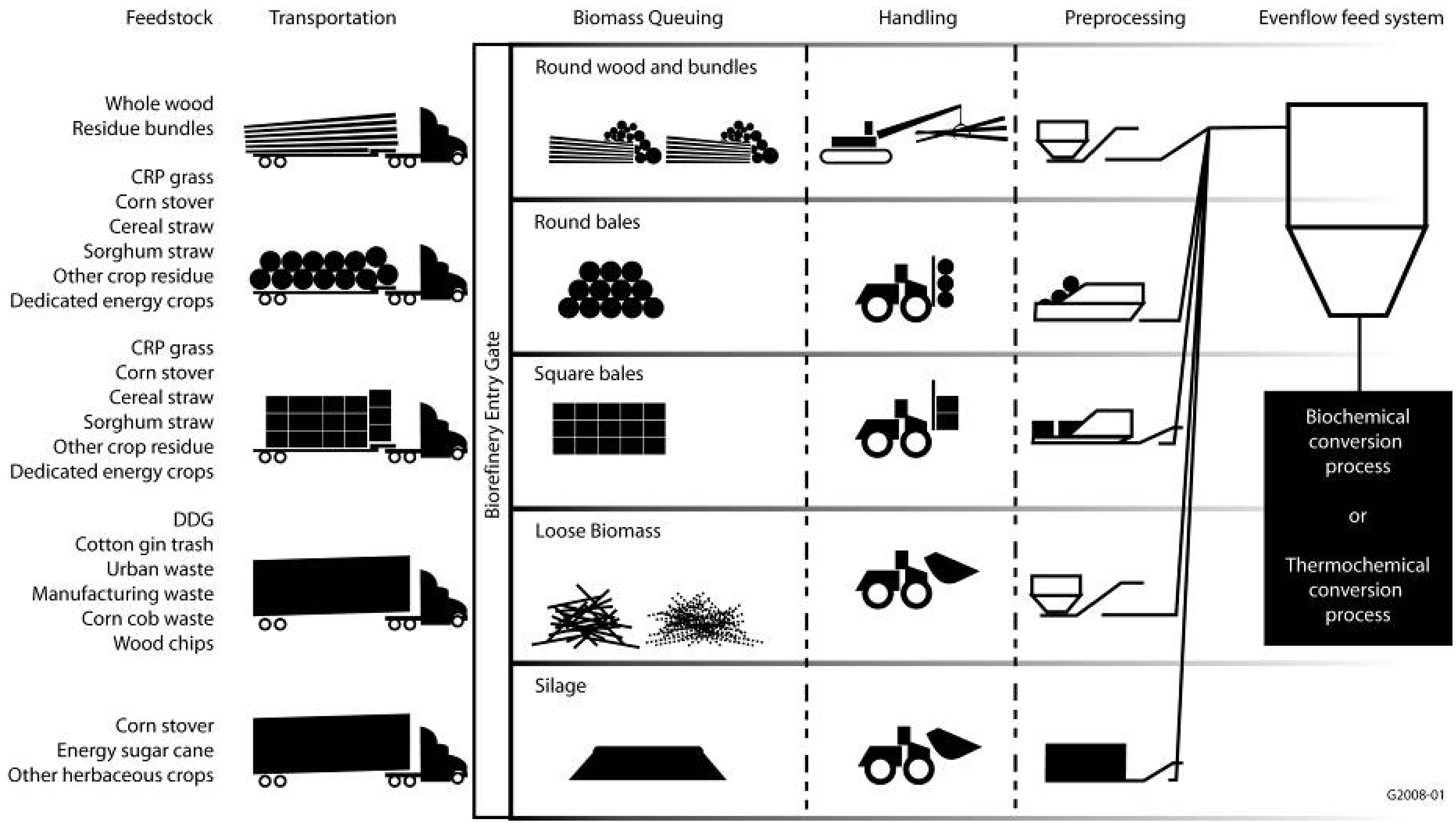
R&D Path to the Uniform Feedstock Supply System Design

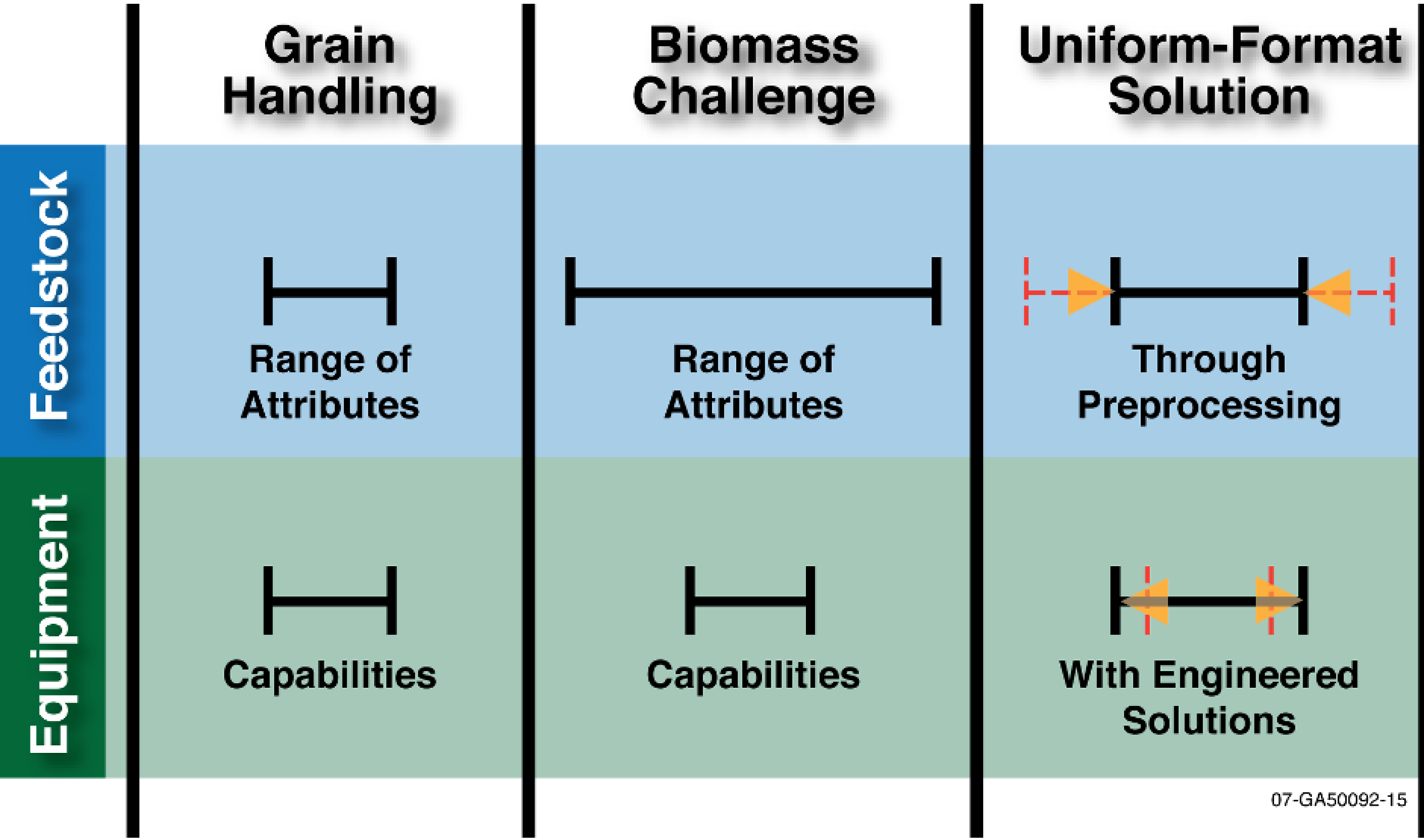
- Moving preprocessing forward in the supply system creates down-stream uniformity and increases system efficiencies



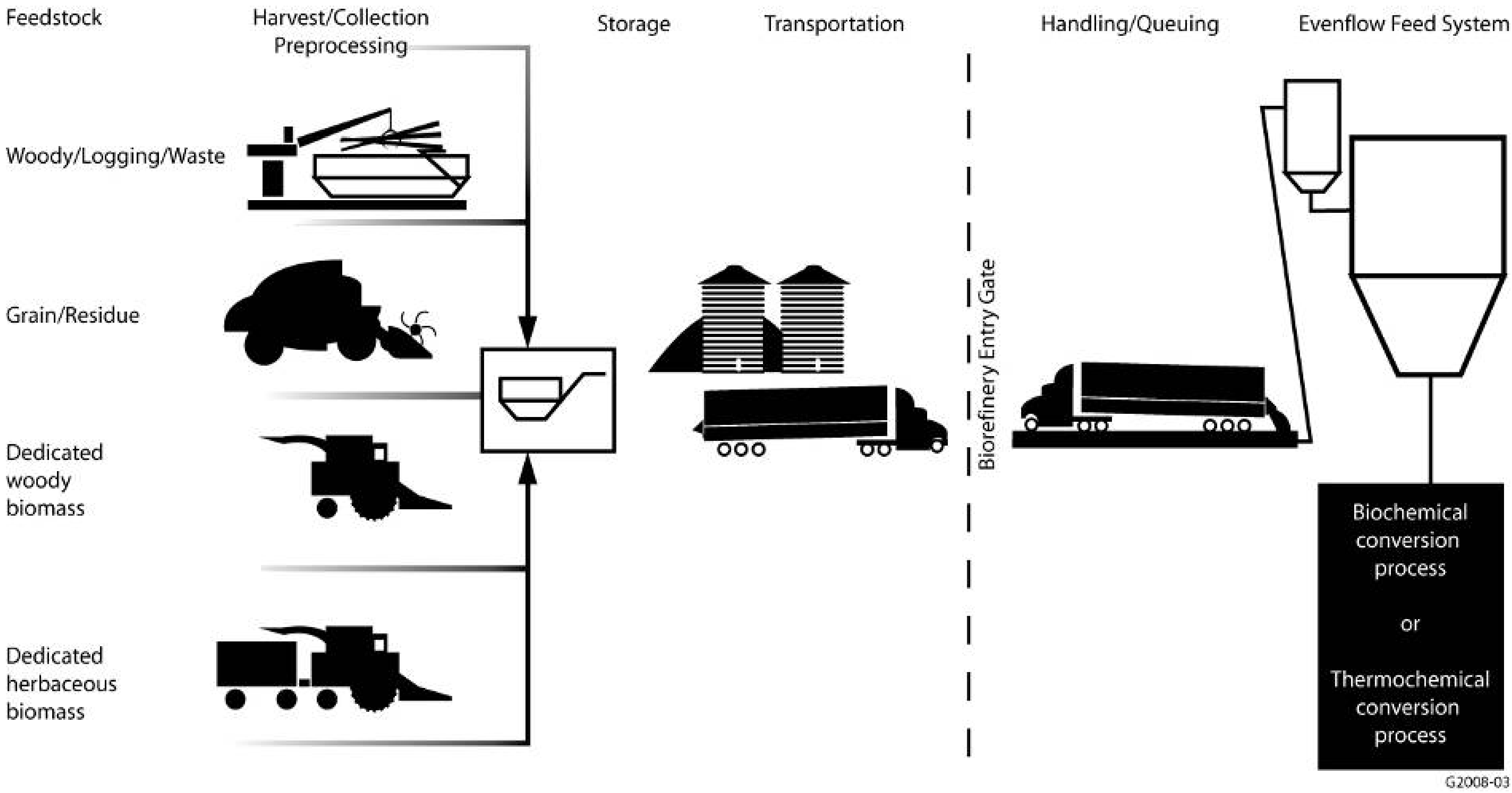
Pioneer Feedstock Supply System



Uniform Format: Alter Feedstock Attributes to Function in Standardized Equipment



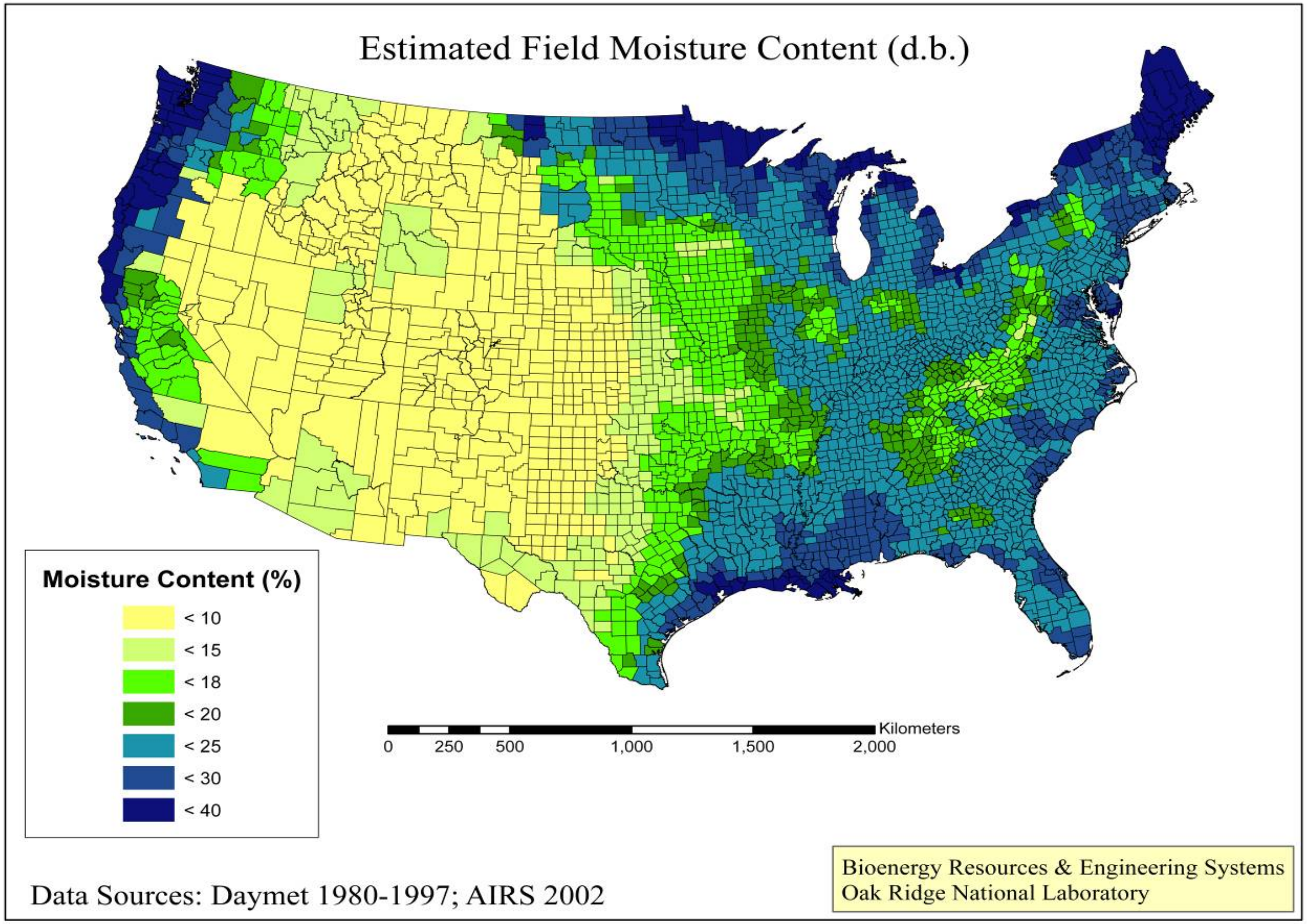
Advanced Uniform Feedstock Supply System Design



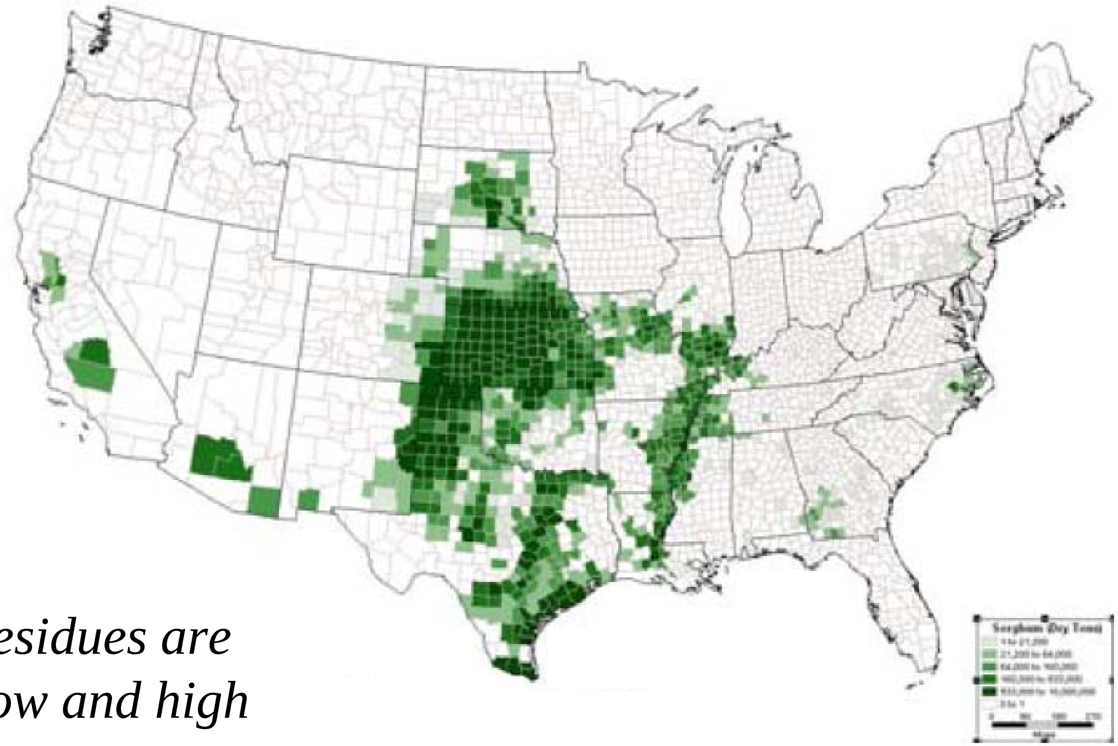
Advanced Uniform Format Target Material Properties

- **Advanced Uniform Format**
  - **Particle Size Distribution**
    - Narrow
  - **Bin Density (10 ft Diameter Bin)**
    - > 30 lbs/ft^3
  - **Compressibility (%)**
    - < 20 %
  - **Flowability Factor**
    - > 4.0 (freely flowing)
  - **Springback**
    - < 3 %

Generalized Wet and Dry Geographic Locations



Sorghum Residue Availability



Current sorghum residues are harvested in both low and high moisture climates:

Dry vs. wet supply chains

Modified from Perlack, et al, 2007

Biomass Storage Configurations and Costs

Dry storage

Tarp: $2/DMT

www.interwrap.com/

Bins: $15/DMT

www.nemog.com/

Bale Wrap: $6/DMT

Bunker: $13/DMT

http://www.uark.edu/depts/agronomy/west/silage/bunker.gif

Wet storage

Silo: $27/DMT

www.uwex.edu/ces/crops/inoc.htm

Large Vertical Structures: $35/DMT

www.wwvrailway.com

Silage Tubes: $24/DMT

http://www.silagrow.com/html/plastics.html#Silage

Drive Over Pile: $11/DMT

learningat.ke7.org.uk/ecoweb/new/silage

Dry Storage Cost Scenarios

Base Case: Kansas Corn Stover
~$6/dry ton

Optimal Case: Idaho Cereal Straw
$1.18/dry ton

Description:

- **Costs include shrinkage, insurance, land rent for stack, stack maintenance, and cover**

Differences:

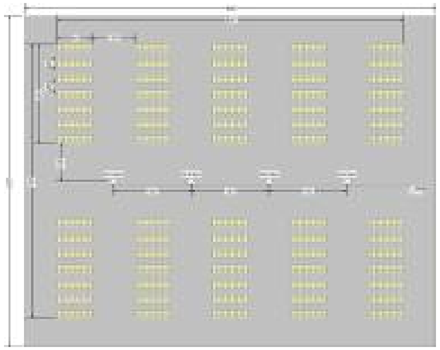
- **ID Straw: Low precipitation , no cover needed**
- **KS Stover: Higher precipitation, bale wrap for loss mitigation**
- **KS Stover: Higher harvest & collection cost results in higher shrinkage cost**

Dry Storage Permitting Examples

- Dust control for grinders, loading, and unloading systems

2903.5 Dust collection. Where located within a building, equipment or machinery which generates or emits combustible fibers shall be provided with an approved dust-collecting and exhaust system. Such systems shall comply with Chapter 13 and Section 511 of the *International Mechanical Code*.

Bale Yard Design



Bale System

- Fire code regulations

2903.4 Agricultural products. Hay, straw, seed cotton or similar agricultural products shall not be stored adjacent to structures or combustible materials unless a clear horizontal distance equal to the height of a pile is maintained between such storage and structures or combustible materials. Storage shall be limited to stacks of 100 tons (91 metric tons) each. Stacks shall be separated by a minimum of 20 feet (6096 mm) of clear space. Quantities of hay, straw, seed cotton and other agricultural products shall not be limited where stored in or near farm structures located outside closely built areas. A permit shall not be required for agricultural storage.

Commercial Bins:
~65,000 ft^3 inventory

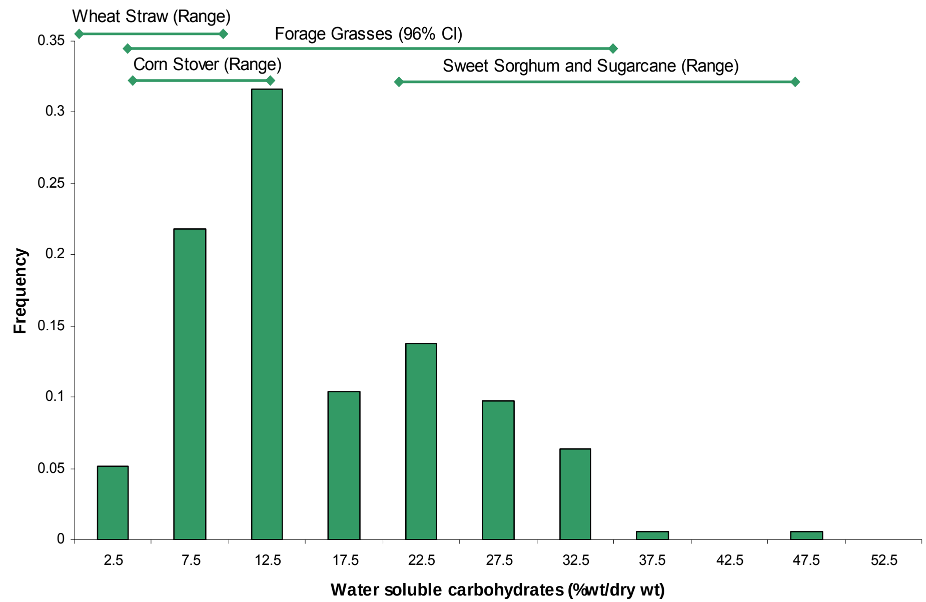
Bulk System

- Fire code regulations

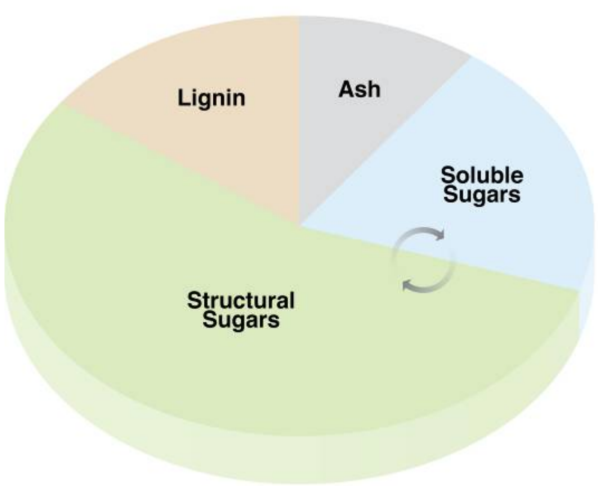
2904.6 Detached storage structure. A maximum of 2,500 cubic feet (70 m^3) of loose combustible fibers shall be stored in a detached structure suitably located, with openings protected against entrance of sparks. The structure shall not be occupied for any other purpose.

Soluble Sugars in Biomass

- Soluble sugars are easily utilized by microorganisms in the supply chain:
  - Self heating, aerobic instability
  - Dry matter loss
- Can soluble sugars be used to make wet storage economical?



Distribution of Major Components in Biomass



Possible Fates of Soluble Sugars in Storage

Loss:
- Utilization by microbes produces cell mass and CO_2

Retention:
- Immediate drying
- Partial ensiling through organic acid production

Stabilization:
- Ensiling through organic acid production
- Value-added products (ethanol, butanol, etc.)

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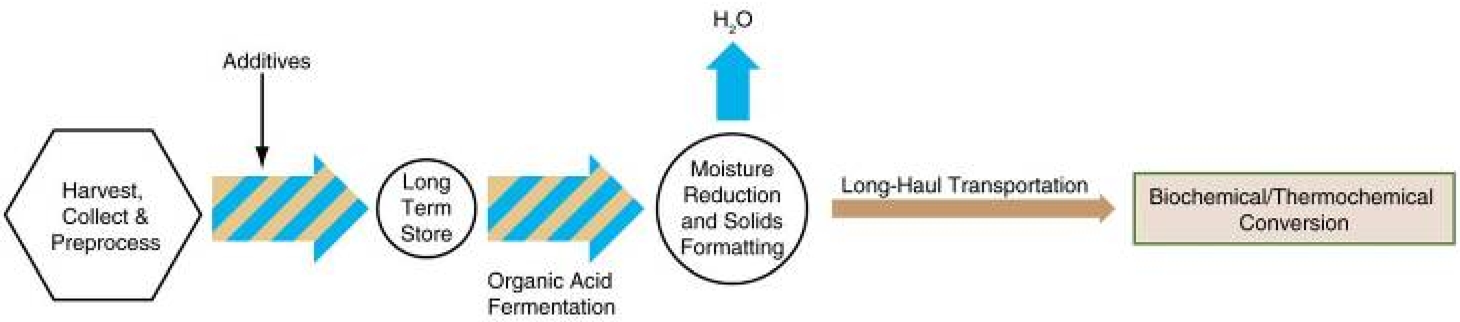
Hybrid Wet / Dry Biomass Feedstock Supply System



<u>Wet Harvested Feedstock Supply Chain</u>

•Necessary to hit tonnage targets

•Cost challenges

–Aerobic instability

–Weight of water

<u>Feasibility of Advanced Fermentations in Wet Storage</u>

•Feedstock cost target ($/DMT)

•Value vs. Delivery/Process Costs of:

–Value-added chemicals from soluble sugars

–Lower pretreatment severity

–Wet/dry hybrid pathways vs. on-field drying

Summary

- Biomass supply chains couple production with refineries and greatly impact:
  - total incurred feedstock purchase price
  - feedstock quality (+ and -)
  - available feedstock tonnages

- Supply chain designs need to be iteratively developed with both producers and industry

- Advanced Uniform Feedstock Supply Chain
  - will allow much greater tonnages and
  - allow for commodity-scale lignocellulosic supply chain

- Wet-harvested feedstock necessary to hit tonnage targets
  - moisture management necessary in supply chain

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Biorefining Depends on Feedstock