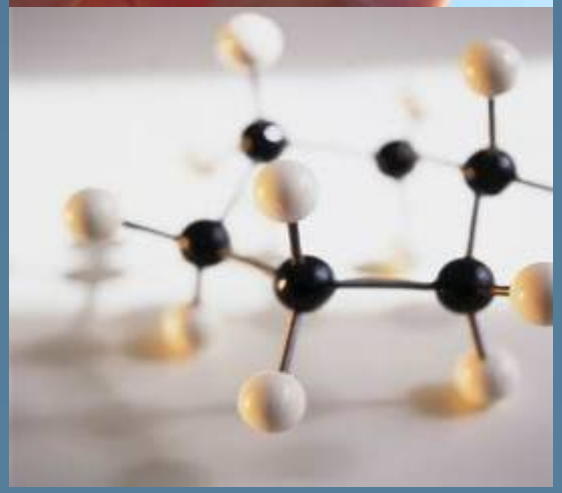


Feedstock-Conversion Interface Projects – Connecting Feedstock Resources to Conversion Processes

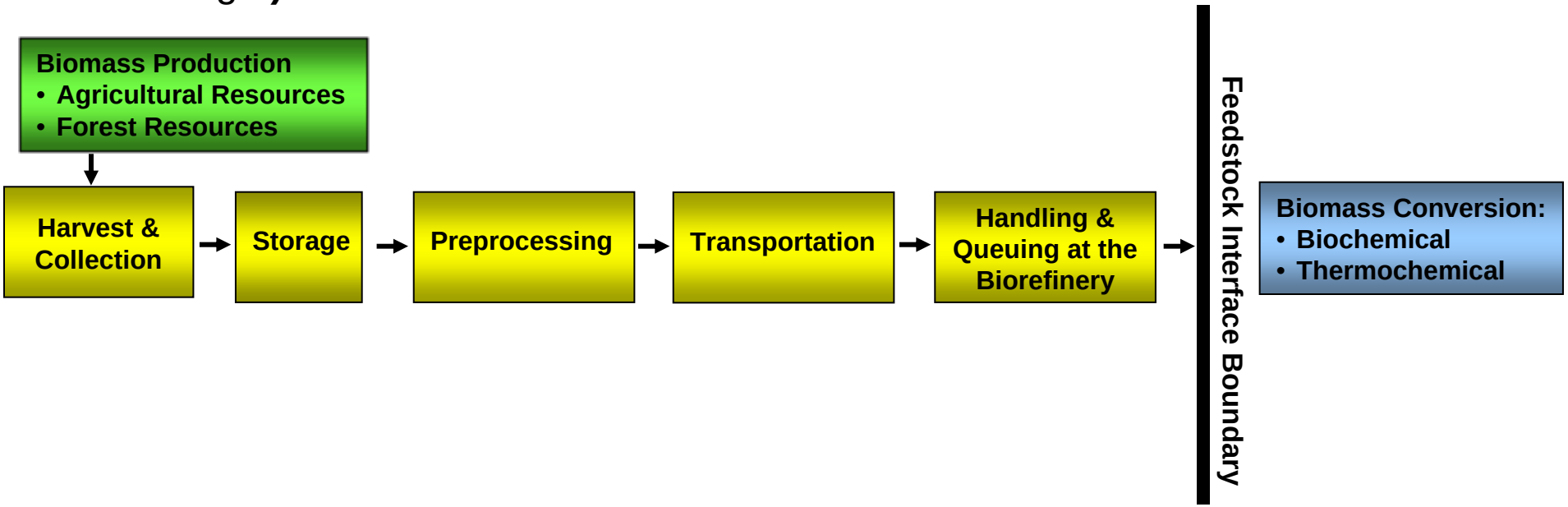
J. Richard Hess et al.
March 31, 2010

Biomass 2010
Arlington, VA

Feedstock Assembly System

Biomass Attributes that Impact Cost and Performance

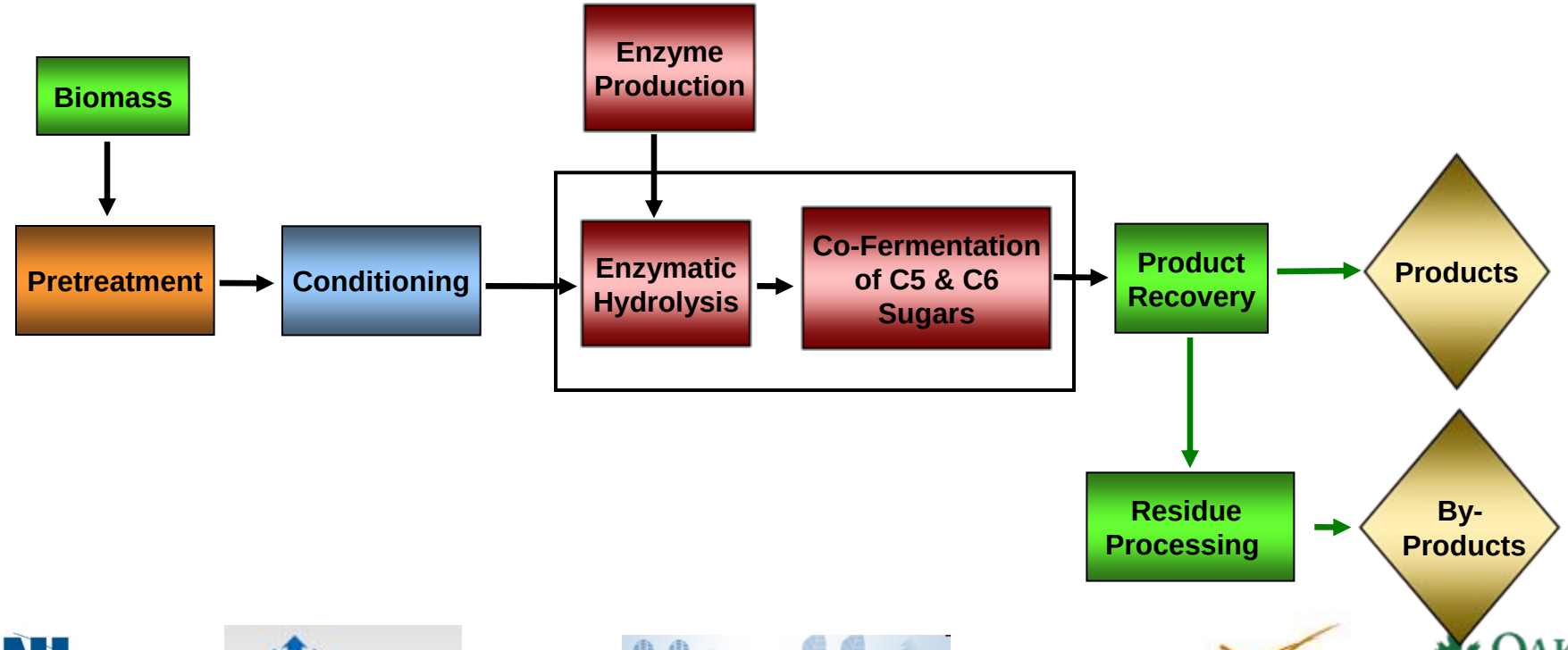
- Physical or Anatomical Structure
- Particle Size and Size Distribution
- Particle Shape and Shape Distribution
- Fractionation Properties (Tensile and Shear Strength)
- Moisture Content
- Material Density
- Flow Properties
- Fines content



Biochemical Conversion

Biomass Attributes that Impact Cost and Performance

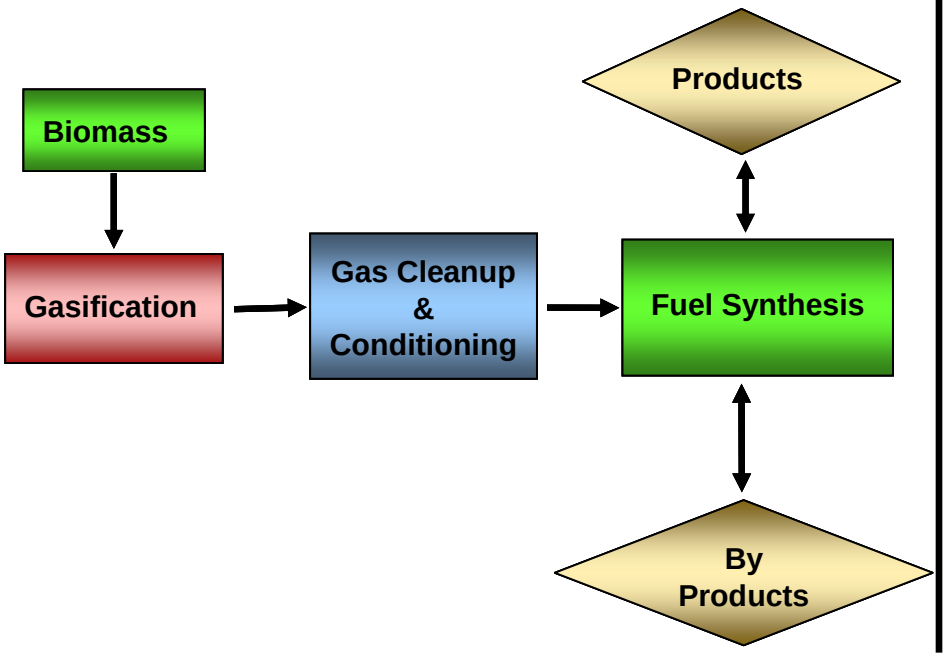
- Structural Sugar Content
- Lignin Content
- Ash Content
- Recalcitrance
- Particle Size
- Fines Content
- Porosity
- Permeability

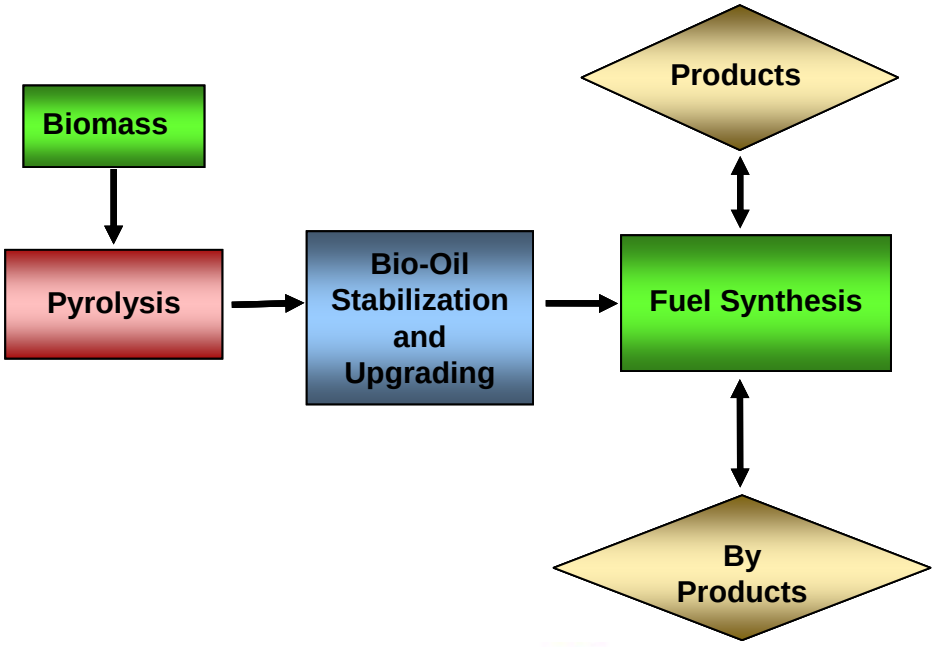


Thermochemical Conversion

Biomass Attributes that Impact Cost and Performance

- BTU Content
- Lignin Content
- S, Cl, N Content
- Ash Content/Composition
- Moisture Content
- Particle Size/Shape
- Material Density
- Thermal Conductivity
- Heat Capacity
- Porosity
- Permeability
- Fines

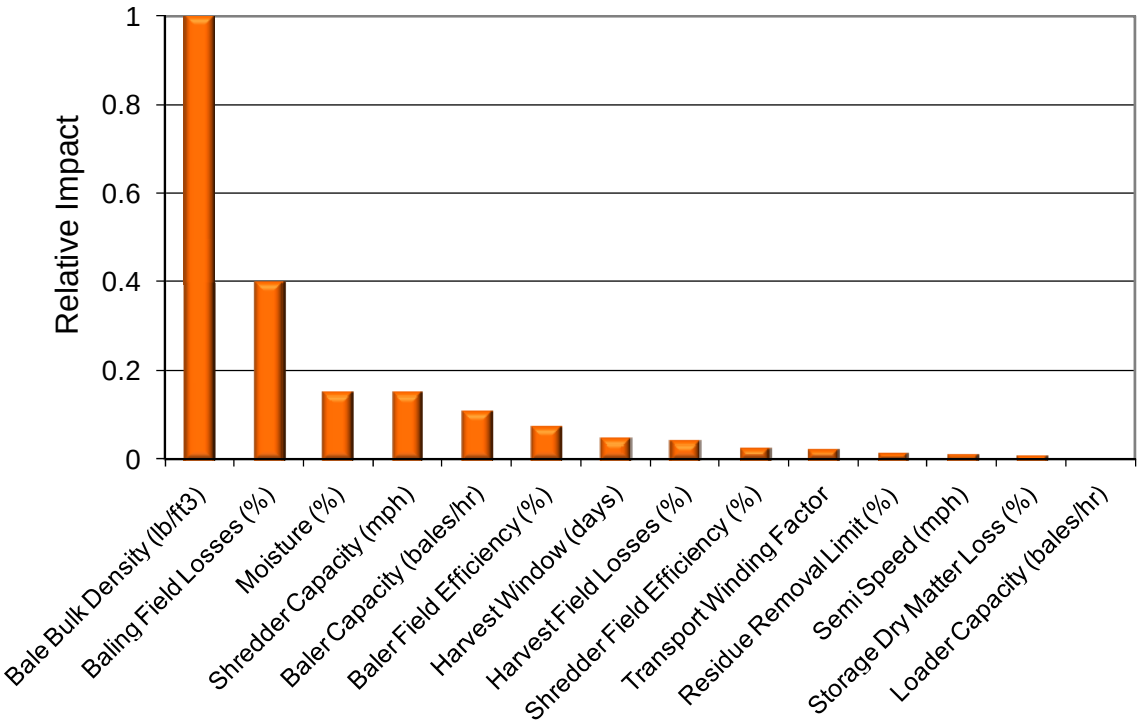




General Biomass Attribute Observations

- Feedstock supply system is most sensitive to physical property attributes
  - **Moisture**
  - **Bulk density**
  - **Plant Material Properties**
- Conversion systems are most sensitive to compositional attributes
  - **Carbohydrate**
  - **Lignin**
  - **Ash**
- Conversion systems may also be sensitive to physical properties, depending upon process design
  - **Moisture**
  - **Particle size and size distribution**

Ranking Factors Influencing Cost



DM Bulk Density Targets

(point where bulk density is not a limiting factor) :

Collection & Transportation

- 16 lbs/ft^3

Handling & Storage

- >30 lbs/ft^3

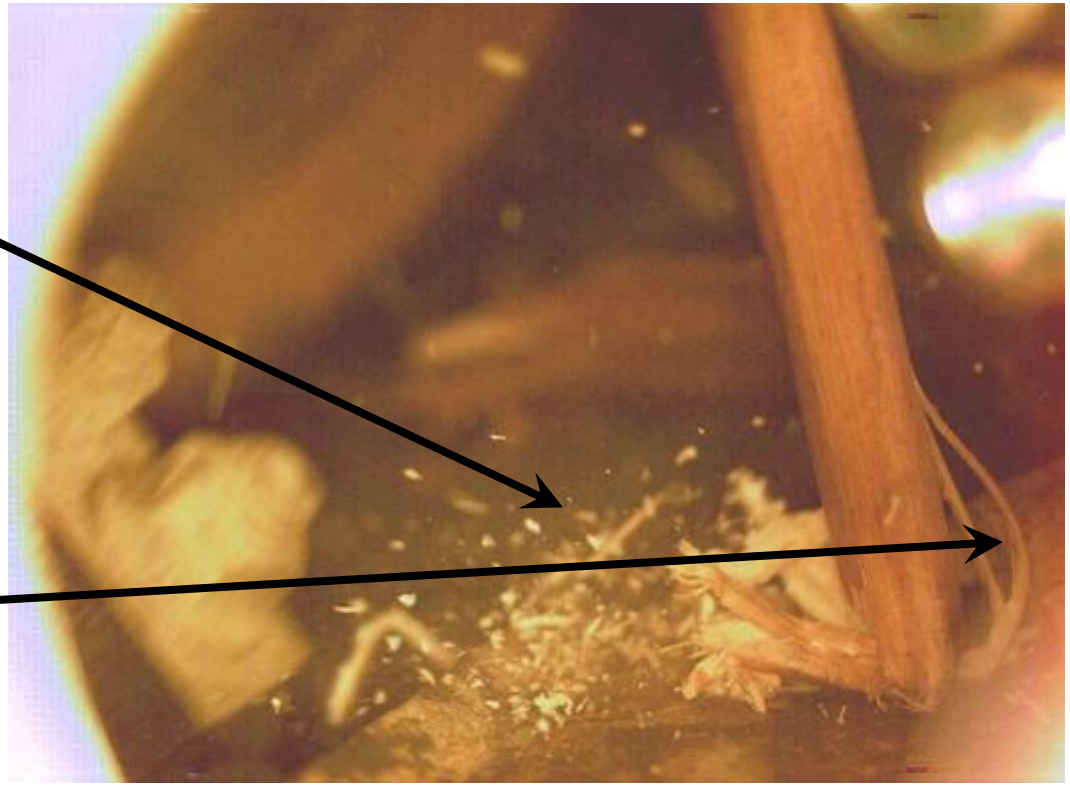
	Baled Yield (DM ton/acre)	DM Bulk Density (lb/ft^3)	Bales (4×4×8-ft) /Acre	Bales (3×4×8-ft) /Acre
Corn Stover	1.6	8–9	2.8–3.1	3.7–4.2
Cereal Straws	1.1	7–9	1.9–2.5	2.6–3.1
Switchgrass	4.0	11–12	7.0–7.8	9.3–10.4
Miscanthus	5.1	9–11	8.9–10.0	11.8–13.3

Idaho National Laboratory
Oak Ridge National Laboratory

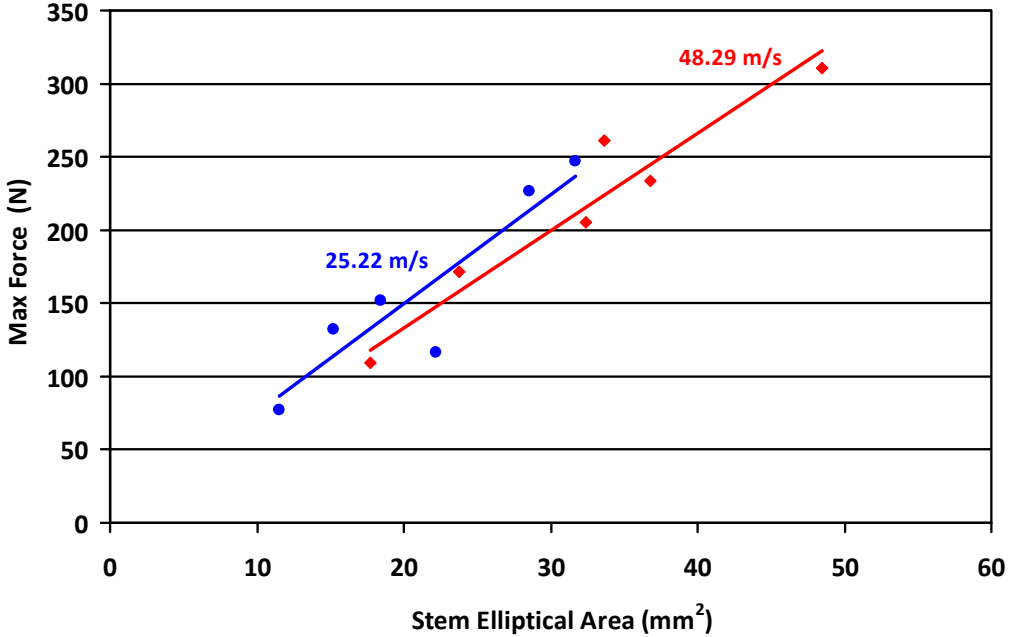
Real Time Fragmentation of Corn Stover during Grinding

Biomass Differential Deconstruction:

- Pith and other tissues rapidly deconstruct upon impact
- Rind and vascular tissues hold together under impact forces and require shear / torsion forces to effectively size reduce



Impact of Hammer Velocity on Miscanthus Fragmentation Properties

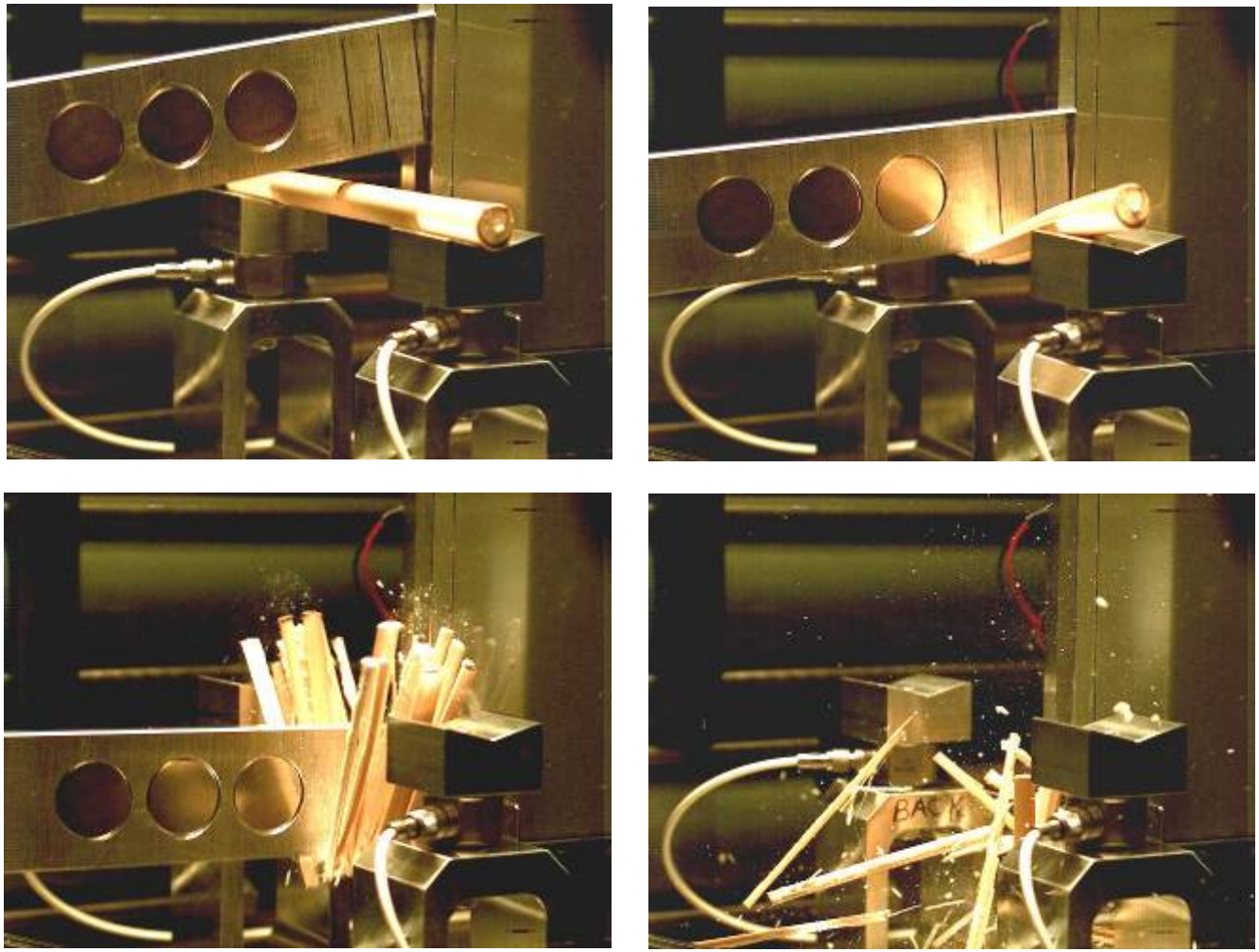


Sample Particulate Generated at 25 m/s

Maximum force required to break miscanthus stem as function of hammer speed and stem elliptical area

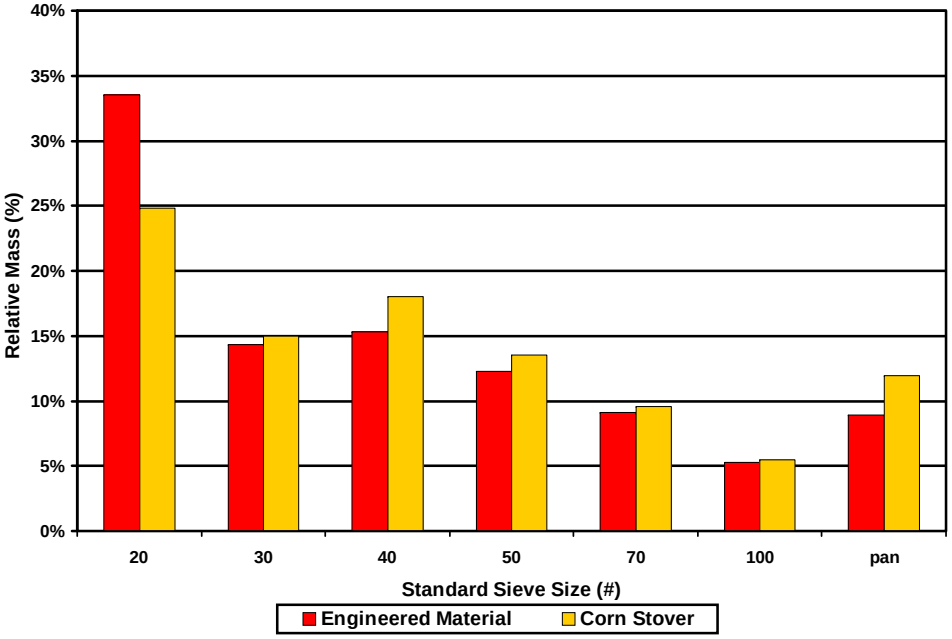
Sample Particulate Generated at 50 m/s

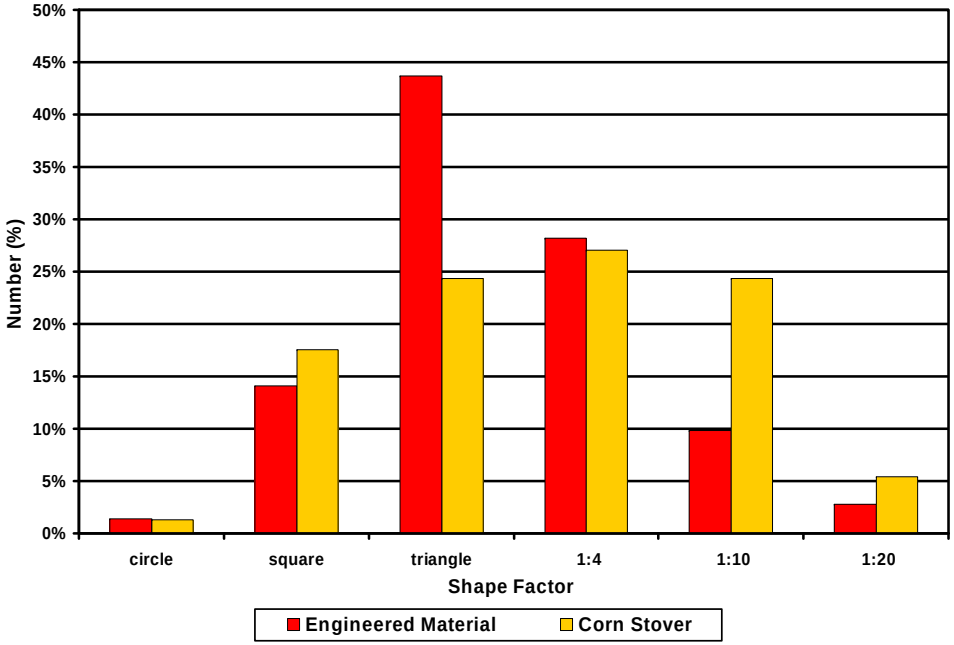
Impactor Study with Miscanthus



Deconstruction of previously baled miscanthus stalk at a hammer speed of 25 m/s

Comparison of ¼- Corn Physical Properties as a Function of Format



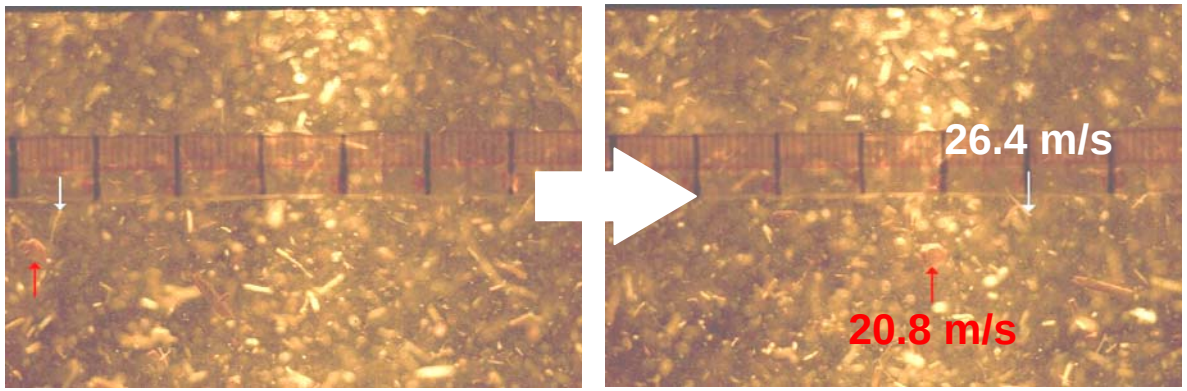


Material Conveying Properties

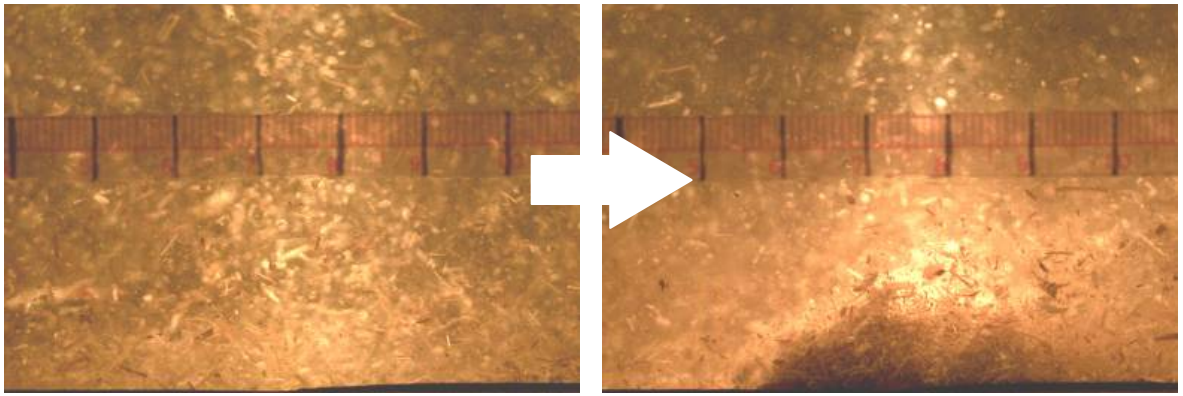
10 ft Bin Diameter 2 ft Opening	Engineered Material	Corn Stover
Flow Rate (lb/min)	2432	345
Feed Density (lb/ft^3)	26.9	7.4
Bin Density (lb/ft^3)	30.0	9.1
Compressibility Factor	12%	23%
Permeability (ft/sec)	0.24	0.18
Springback (%)	3.76	4.72
Angle of Repose	39.2°	35.3°

Material Conveying Properties

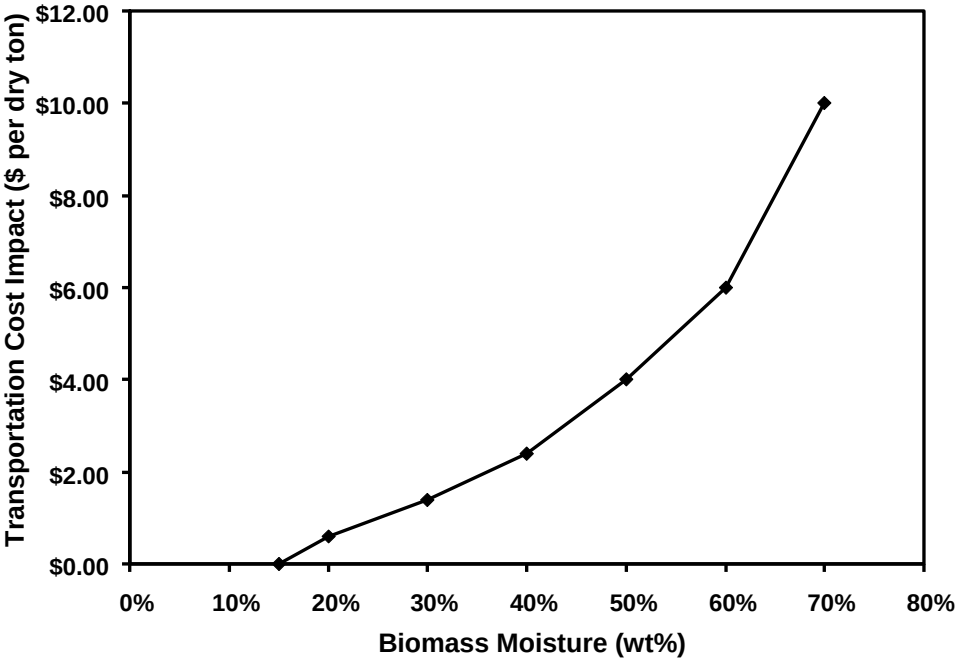
Velocity as Function of Size and Shape



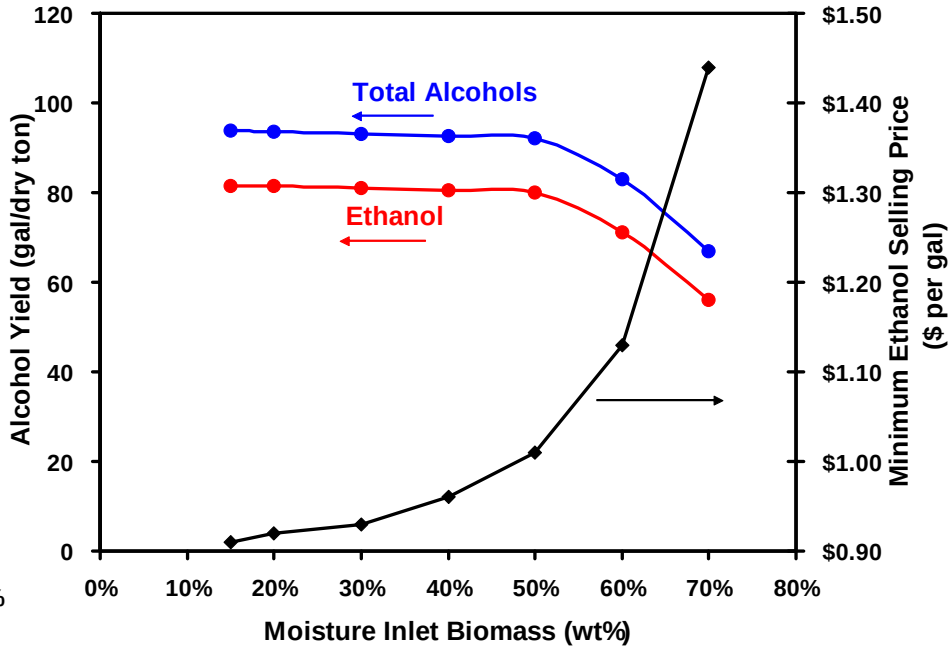
Stratification as a Function of Mass Loading



Impact of Moisture in Feedstock Supply and Gasification Systems



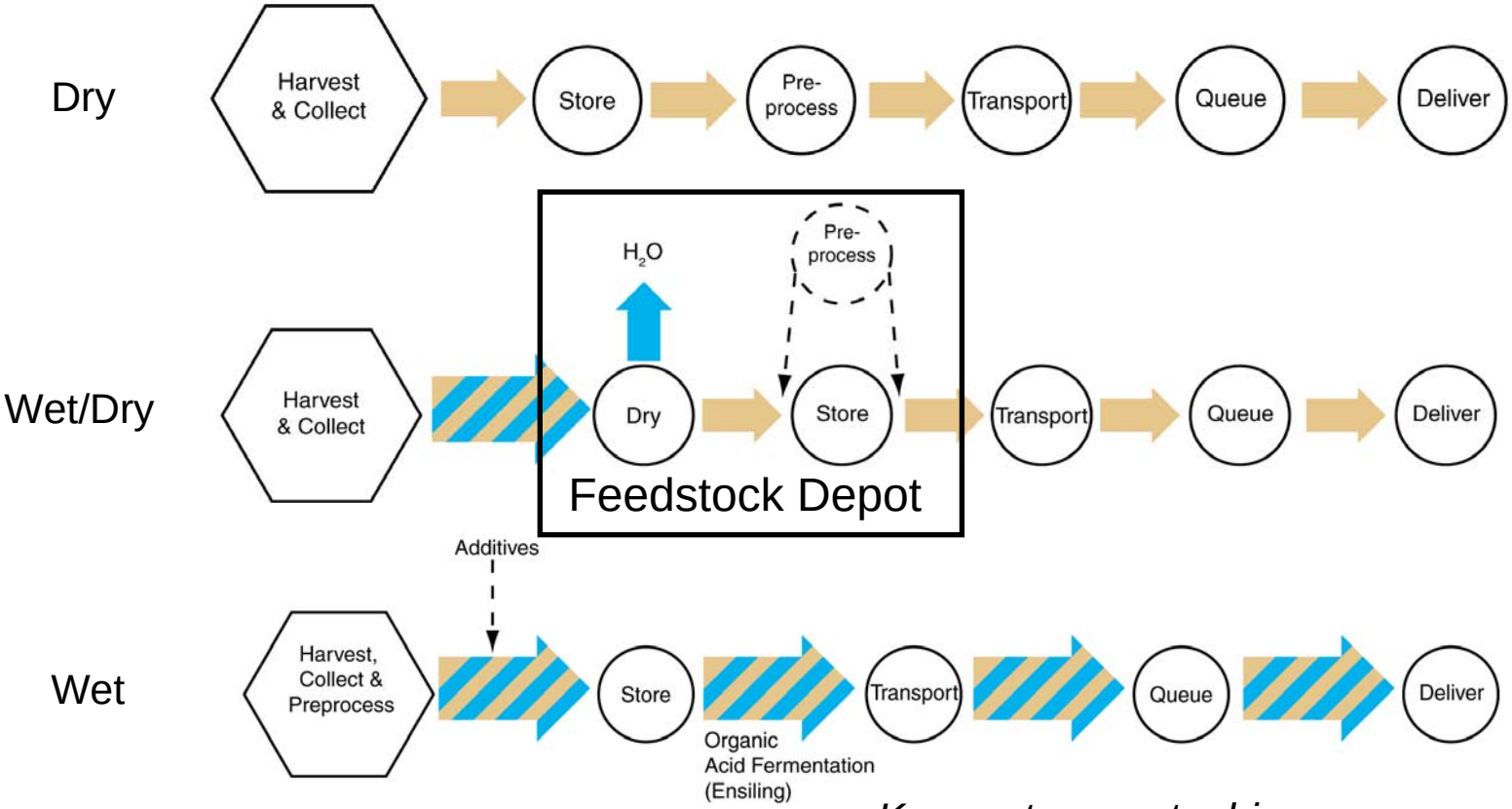
Transportation Cost Sensitivity



Gasification Process Cost Sensitivity[1]

[1] NREL Technical Report, TP-510-41168, 2007

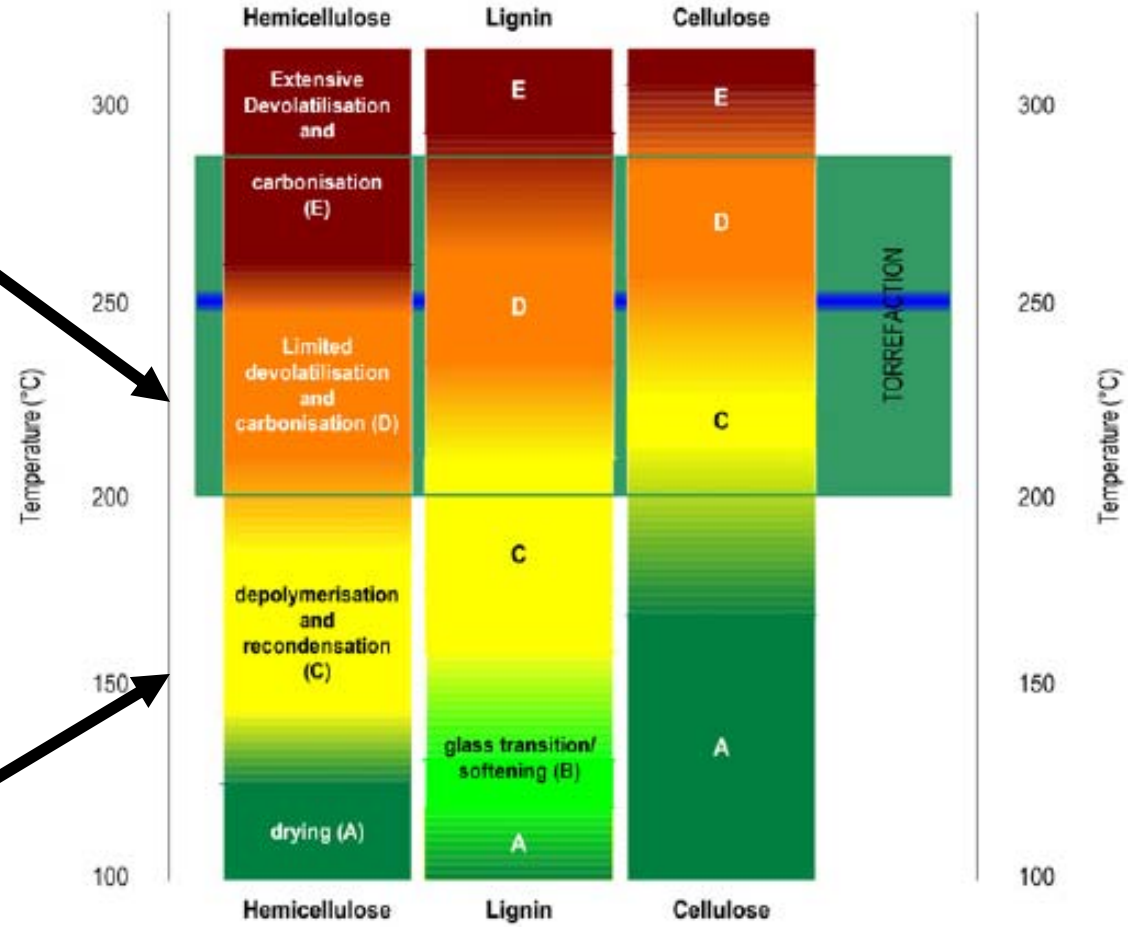
Biomass Moisture Management Supply System Concepts



Wet and dry system integration!

<u>Key system costs drivers:</u>
-harvest and collection
-storage
-drying
-wet handling and transportation
-aerobic stability mitigation & impacts

Thermal Treatment & Stabilization Processes

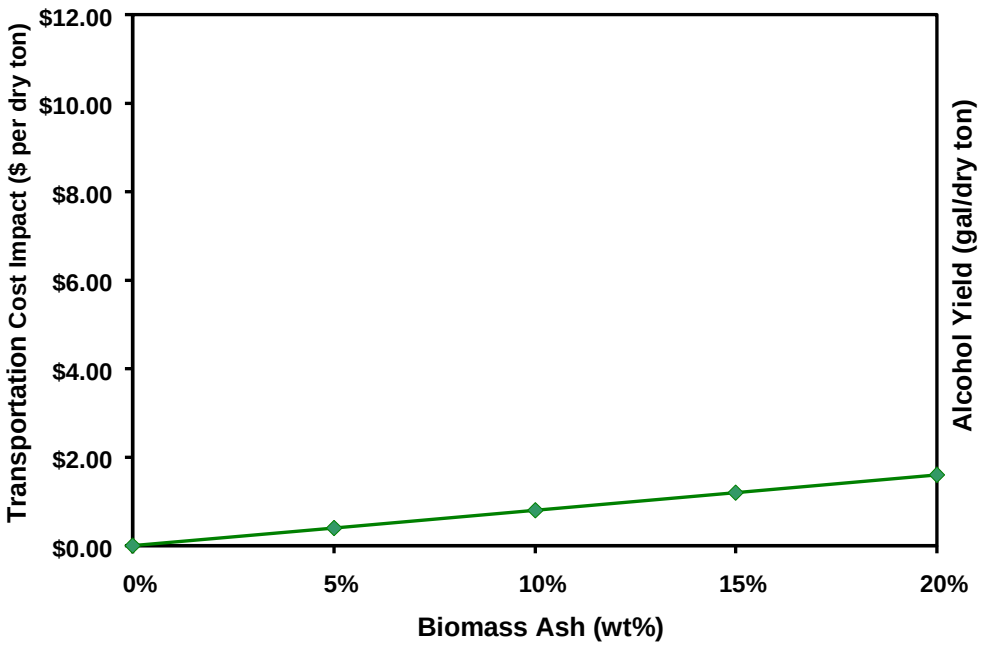


[4] Bergman, P.C.A., et al., *Torrefaction for biomass co-firing in existing coal-fired power stations. BIOCOAL.* 2005. p. Size: 72 pages.

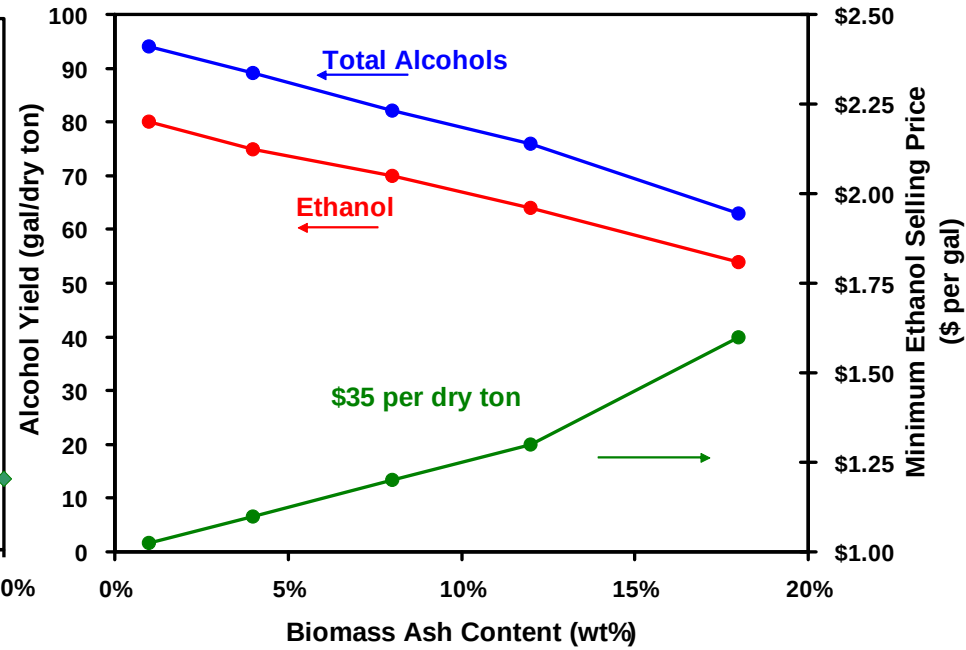
Torrefaction

- Thermal treatment process
  - 200-300 ºC, ~atm pressure, no oxygen
  - Low heating rate < 50 ºC/min
  - 15-30 minute residence time
- Advantages
  - Higher energy density
    - Lower O:C
  - More Stable
    - Low moisture
    - Hydrophobic
  - Easier to process, more friable, less fibrous
    - 50-85% reduction in grinding power reported

Impact of Ash in Feedstock Supply and Gasification Systems



Transportation Cost Sensitivity



Gasification Process Cost Sensitivity[1]

[1] NREL Technical Report, TP-510-41168, 2007

Corn Stover Harvest -Conventional Bale

Windrowing Treatment (Sample#)	Composition %				
	Ash	**Non-Struct Inorganics**	**Total Extractives**	**Lignin**	**Total Sugars**
I	12.2	8.3	11.0	16.7	64.7
II	25.2	16.8	12.3	17.2	58.1
III	9.8	5.8	13.3	17.0	60.4
IV	11.9	6.8	13.0	18.2	57.5
V	11.2	6.9	13.9	16.7	49.6
VI	7.2	3.0	13.8	22.6	66.2
VII	11.3	6.1	13.7	18.7	65.4
VIII	13.5	7.2	12.3	16.5	65.0
IX	9.8	5.2	13.6	16.6	65.4
X	12.7	6.9	8.7	18.2	64.5

Preprocessing Impact on Feedstock Biochemical Quality

Tray 2

Tray 4

Tray 6

Pan

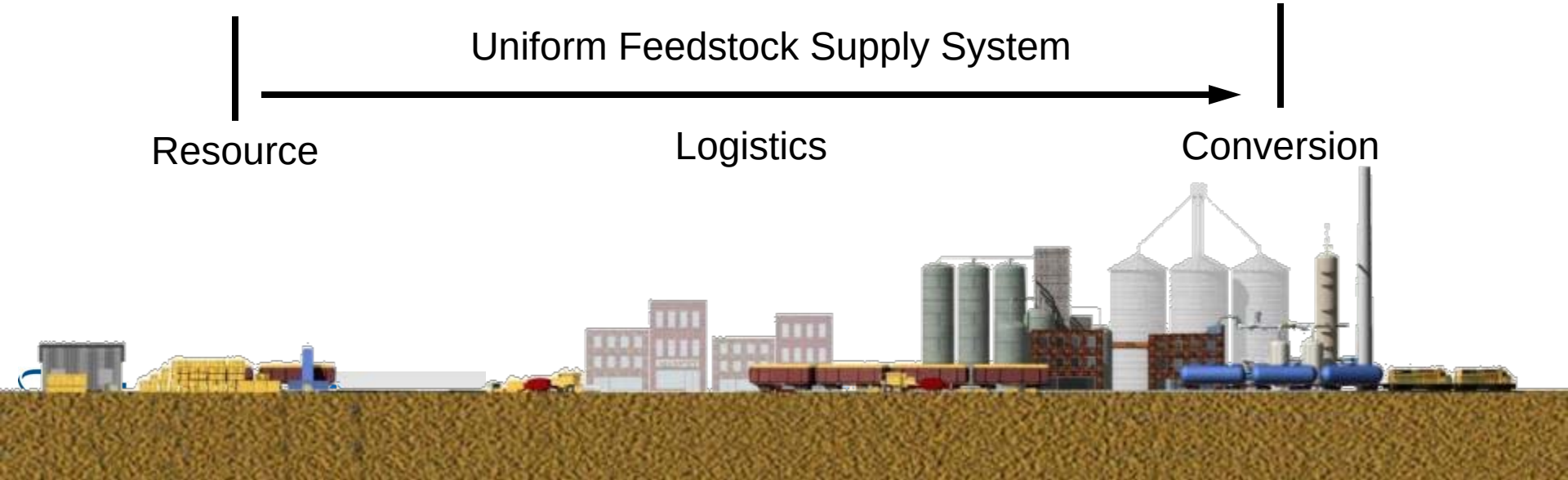
Grinder Screen 2-inch	GLUCAN (%)	XYLAN (%)	GALACTAN (%)	ARABINAN (%)	Total Sugars
No Screen	36.57	16.68	0.91	1.70	55.86
Tray 2	39.74	16.77	0.78	1.36	58.65
Tray 3	39.08	16.98	0.79	1.44	58.29
Tray 4	37.80	16.99	0.84	1.54	57.18
Tray 5	36.11	17.24	1.00	1.64	55.99
Tray 6	31.76	16.04	1.32	1.83	50.95
Pan	22.39	11.93	1.82	1.80	37.94

Preprocessing Impact on Feedstock Thermochemical Quality

	No Screen	Tray 3	Tray 4	Tray 5	Tray 6	Pan
Proximate Analysis (% dry fuel)						
Fixed C	11.06	12.17	12.73	13.37	12.68	11.63
Volatiles	70.40	85.29	84.25	82.37	78.43	79.87
Ash	18.54	2.54	3.02	4.26	8.89	8.50
Ultimate Analysis (% dry fuel)						
C	41.60	49.79	49.63	49.12	46.69	46.93
H	4.98	5.73	5.72	5.69	5.41	5.44
O (Diff.)	34.25	41.75	41.39	40.70	38.65	38.83
N	0.57	0.16	0.17	0.18	0.29	0.24
S	0.06	0.03	0.07	0.05	0.07	0.06
Cl	0.016	0.023	0.018	0.022	0.016	0.016
Elemental Composition of Ash (%)						
SiO_2	79.17	69.07	70.67	72.21	77.32	77.31
K_2O	2.44	9.45	7.67	6.09	3.52	3.68
NaO_2	0.59	0.36	0.63	0.38	0.85	0.55
MgO	0.89	2.68	2.55	1.82	1.40	1.31
CaO	2.71	4.92	4.86	4.36	3.20	2.88
P_2O_5	0.88	3.95	3.30	2.62	1.42	1.40
Fe_2O_3	2.76	1.83	2.02	2.35	2.67	2.81
Al_2O_3	6.20	2.80	3.71	4.02	5.68	5.92
TiO_2	0.36	0.22	0.21	0.21	0.31	0.31
Higher Heating Value (Btu/lb)						
HHV	6906	8050	8146	7944	7743	7705

Linking Feedstocks to Conversion

- Connect the Diversity of Feedstock Resources to Biochemical and Thermochemical Conversion Facilities/Processes
  - **Improve Feedstock Supply System Logistics**
  - **Enable Commodity Scale Lignocellulosic Supply System**



Feedstock-Conversion Interface Project Team

Material Properties and Biomass Library:

- Pete Pryfogle, INL,
  Rheological testing methods development & Biomass Library Maintenance
- Judy Partin, INL,
  Rheological testing methods development
- Tom Ulrich, INL,
  Biomass Library Sample Collection
- Jake Jacobson, INL,
  Biomass Library Database
- David Muth, INL,
  Biomass Library Database
- Garold Gresham, INL,
  Biomass Library Coordination

- Nick Nagle, NREL,
  Biochem sample collections
- Ed Wolfrum, NREL,
  Biochem sample collections

Chemical Properties – Biochem:

- Nick Nagle, NREL,
  Conversion Interface requirements
- Ed Wolfrum, NREL,
  Rapid screening methods development
- Ryan Ness, NREL,
  Screening method development (ASE 350)
- David Templeton, NREL,
  Attribute characterization

- Garold Gresham, INL,
  Feedstock Interface requirements & Attribute characterization
- William Bauer, INL,
  Screening method development

Chemical Properties – Thermochem:

- David Eakin, PNNL,
  Thermochem in-feed requirements
- Scott Butner, PNNL,
  Thermochem in-feed requirements

- Kim Magrini-Bair, NREL,
  Thermochem in-feed requirements
- Calvin Feik, NREL,
  Thermochem in-feed requirements

- Judy Partin, INL,
  Attribute characterization and Rapid screening development