Uniform Format Design and Deployable Process Demonstration Unit

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Herbaceous Feedstock Logistics
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Basis of Feedstock Supply System R&D

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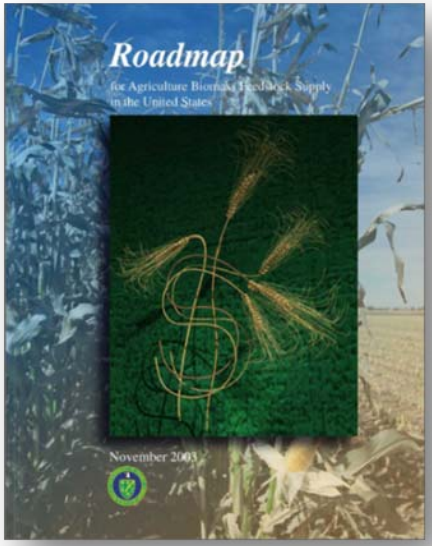
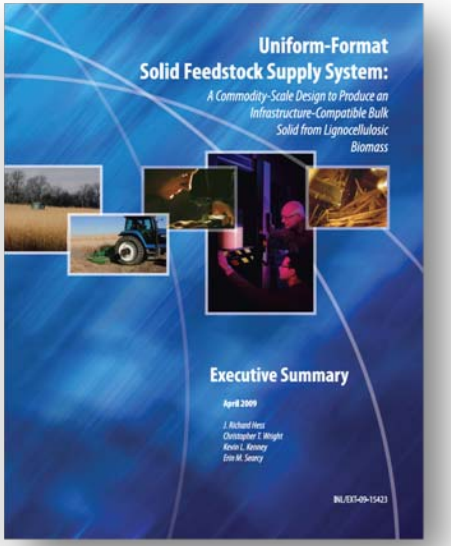
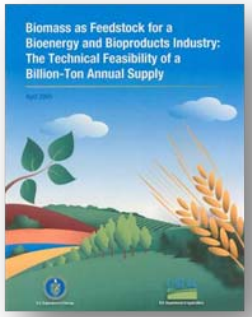






Biomass Production:
- Ag. Resources
- Forest Resources

Feedstock Production Interface

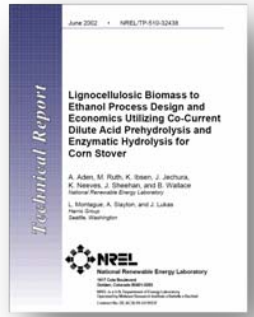
Harvest & Collection
- Equipment Capacity
- Compositional Impacts
- Pretreatment Impacts

Storage
- Shrinkage
- Compositional Impacts
- Pretreatment Impacts
- Soluble Sugar Capture

Preprocessing
- Equipment Capacity
- Equipment Efficiency
- Material Bulk Density
- Compositional Impacts
- Pretreatment Impacts

Transportation
- Truck Capacity
- Loading compaction
- Loading efficiencies

Handling & Queuing
- Handling efficiencies
- Handling compaction
- Material Bulk Properties

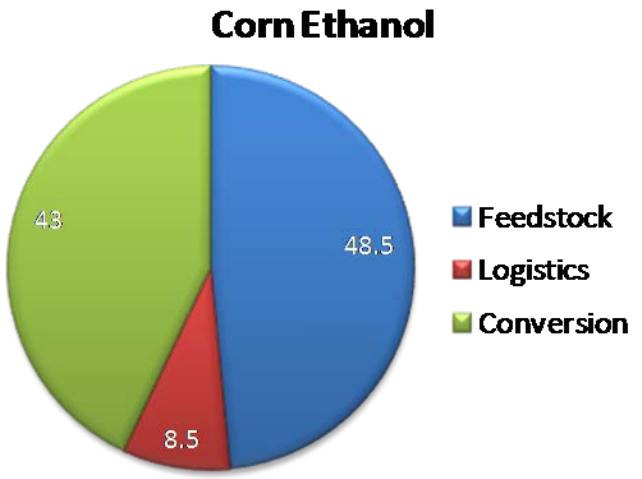


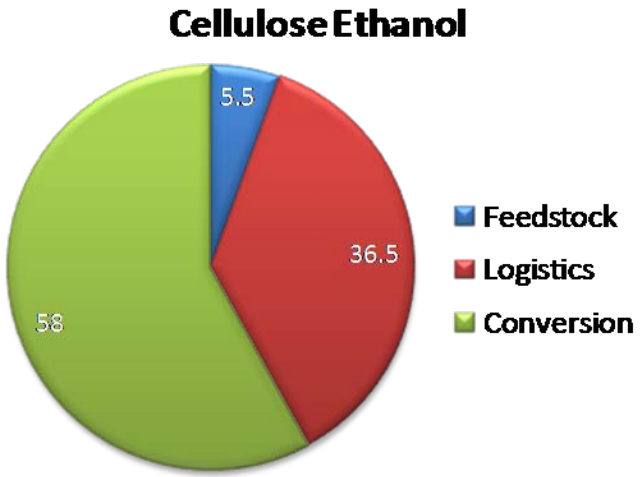
Biomass Conversion:
- Biopower

Feedstock Conversion Interface

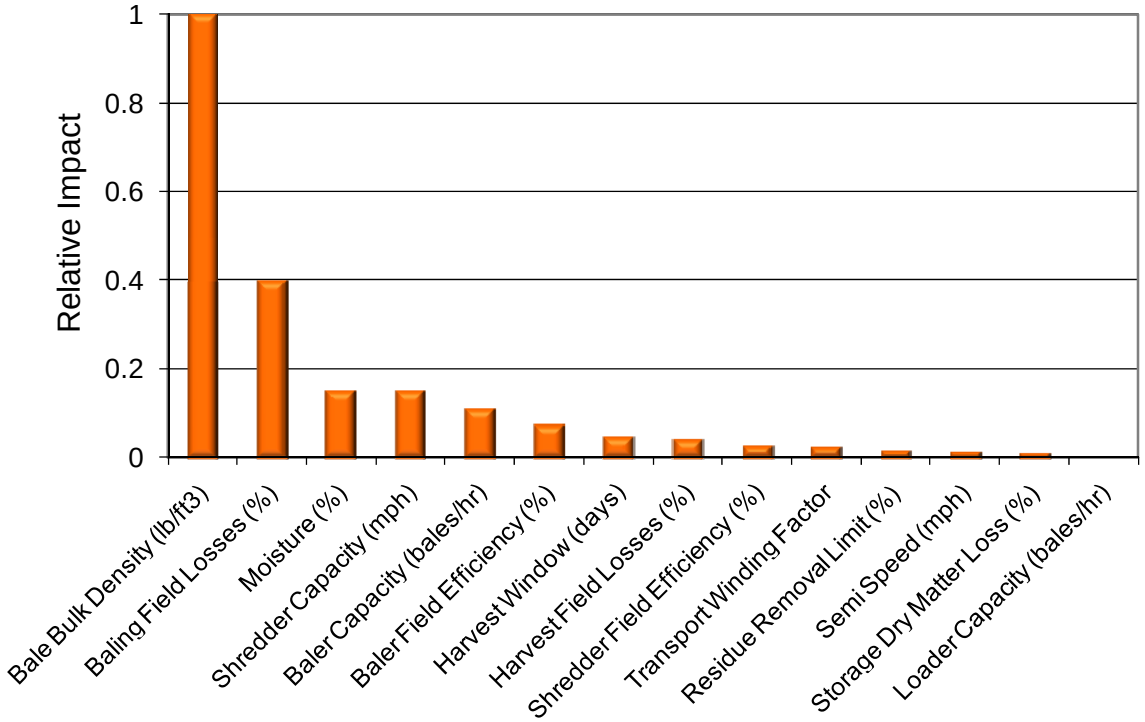
Critical Biomass Attributes and Barriers

- Handling Attributes
  - Bulk density
  - Flowability
  - Particle size, shape, & distribution
  - Moisture content
  - Compressibility
- Conversion Attributes
  - BTU content
  - Energy density
  - Moisture content
  - Ash content & chemistry
  - Carbohydrate content
  - Chlorine & alkali content





Ranking Factors Influencing Cost



DM Bulk Density Targets

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

Collection & Transportation

- 16 lbs/ft^3

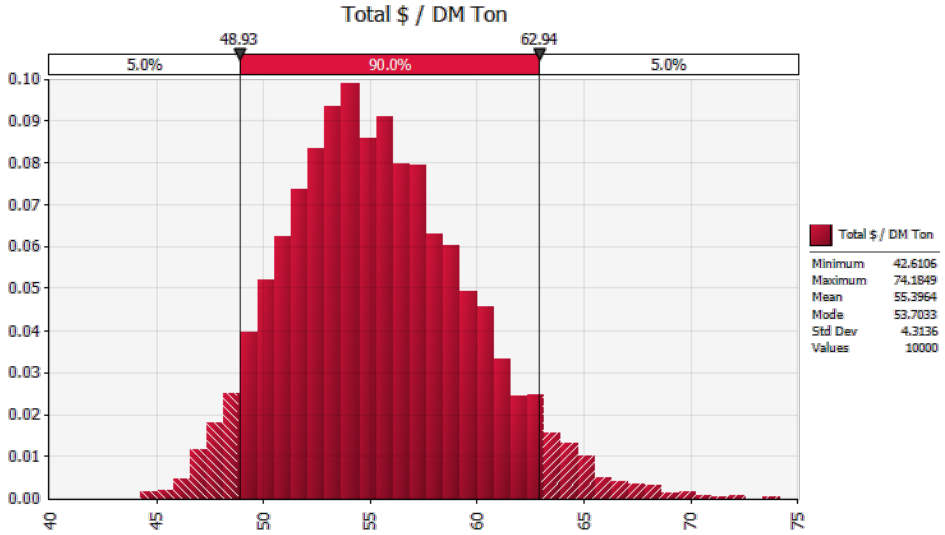
Handling & Storage

- >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

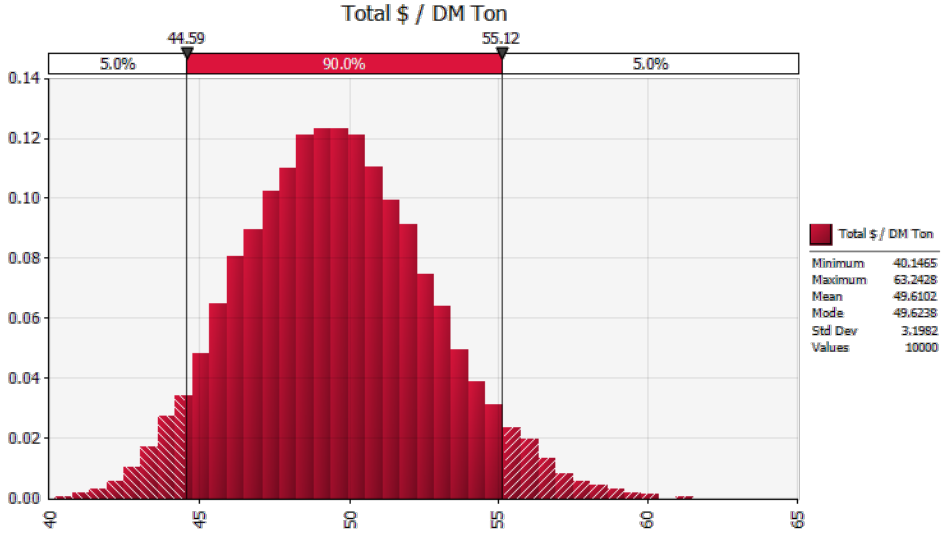
INL Field Data

Conventional Bale Supply System Costs ($2008)



Corn Stover – Lg. Sq. Bale

← Mean = $55.40 / DM ton



Switchgrass– Lg. Sq. Bale

← Mean = $49.61 / DM ton

Critical Biomass Attributes and Barriers

- Handling Attributes
  - Bulk density
  - Flowability
  - Particle size, shape, & distribution
  - Moisture content
  - Compressibility

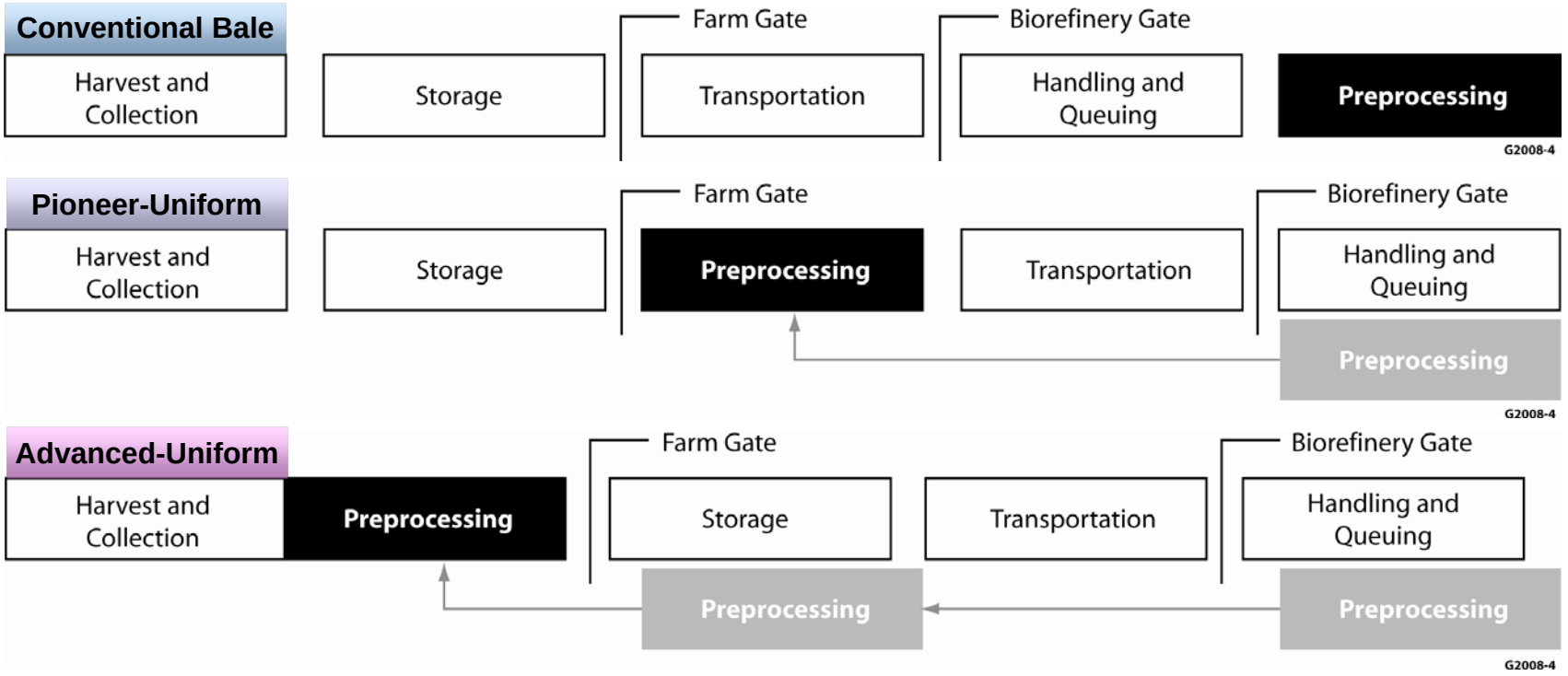
- Size reduction systems
- Thermal treatments
  - drying ➡ torrefaction
- Mechanical Densification

- Conversion Attributes
  - BTU content
  - Energy density
  - Moisture content
  - Ash content & chemistry
  - Carbohydrate content
  - Chlorine & alkali content

- Biomass species/variety
- Fractionation / separation
- Blending characteristics

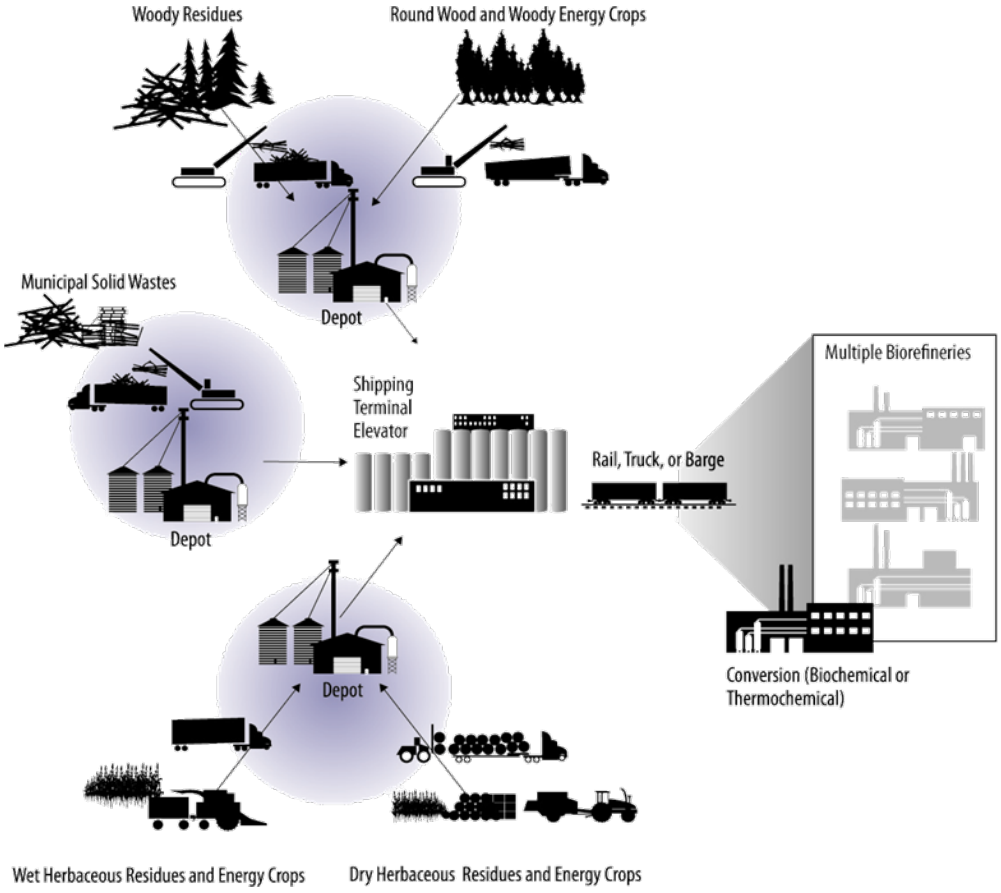
Path to Overcoming Barriers

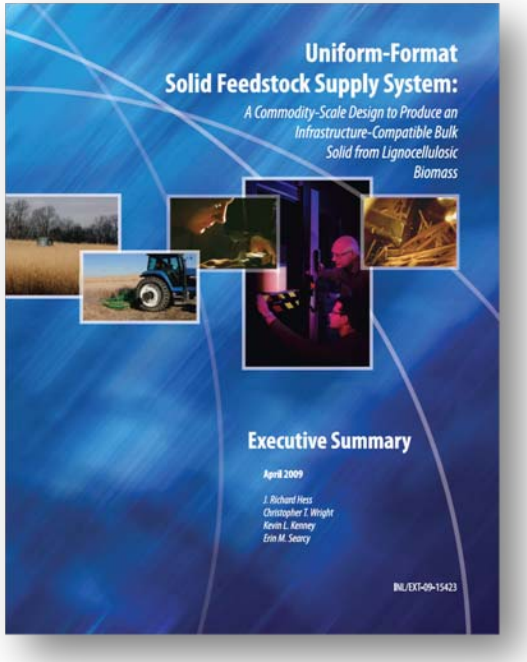
- Harvesting/Collection and Preprocessing are Key Unit Processes
- Harvesting addresses feedstock diversity
- Preprocessing creates down-stream uniformity and increases system efficiencies



Uniform-Format Solid Feedstock Supply System

A Commodity-Scale Design for Bulk Solid Lignocellulosic Biomass





Commodity Attributes:

- National Market
- Governing Body
- Standardized Material/Quality

Depot Products for Biorefinery Input

- Thermochemical Biofuels and Heat/Power Market:
  - Achieving ash, moisture and rheological property specifications
  - Blending to produce a commodity market like corn or coal
- Biochemical Biofuels and Products Market:
  - Achieving carbohydrate structure for specific conversion processes
  - Blending, if at all, within species for a commodity market like wheat
- Petroleum Refinery Market:
  - Achieving energy density and feedstock stability
  - Blending to produce a stabilized liquid “bio-crude” for a commodity market like petroleum crude

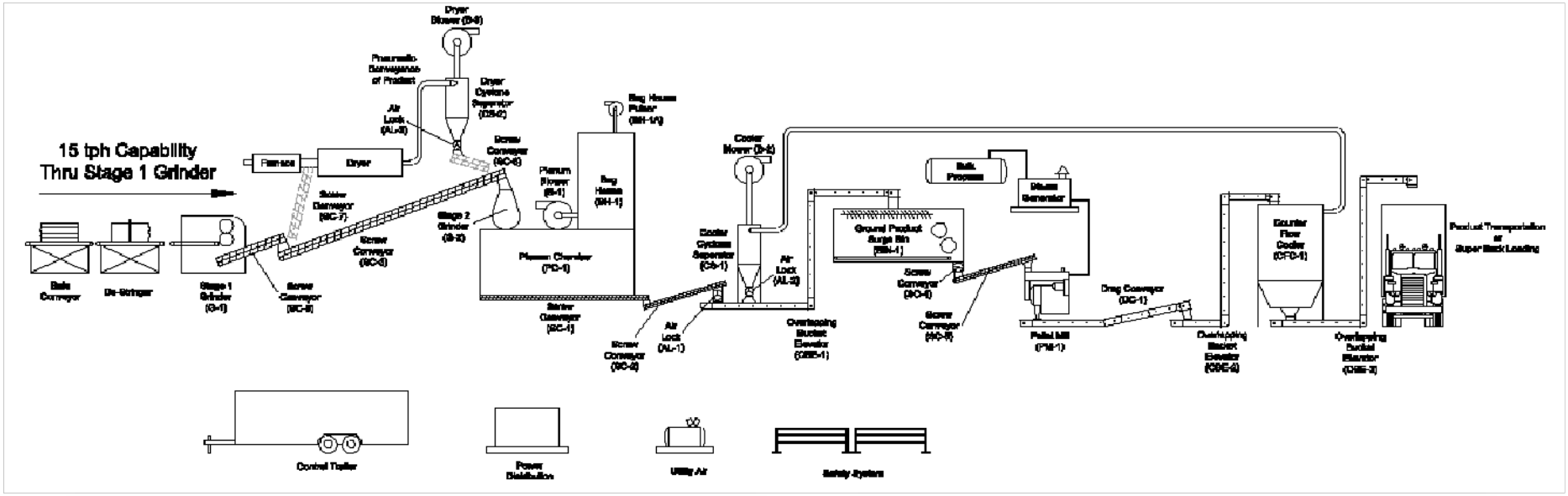
How Do We Build a Commodity Biomass Supply?

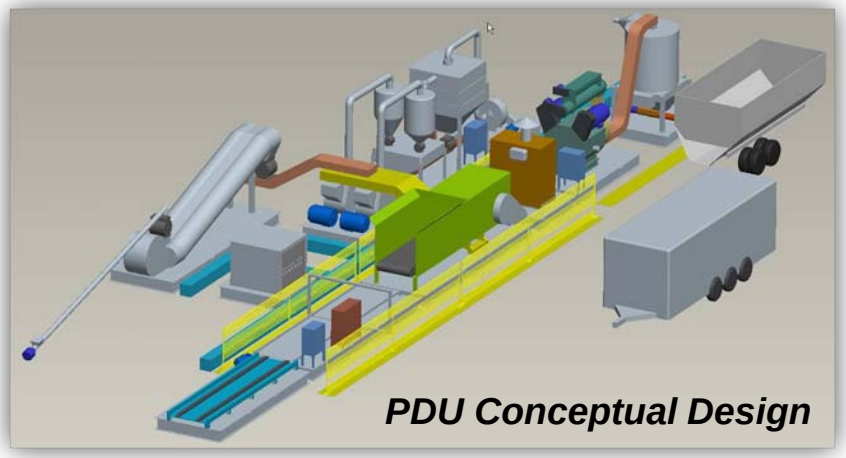
- Assemble a pilot-scale Preprocessing Depot to demonstrate and validate advanced-uniform feedstock supply system technologies
  - A deployable Process Development Unit (PDU)
- PDU approximates one replicable biomass depot described in the Uniform-Format Design Report.
- Major PDU components to be on-line early summer

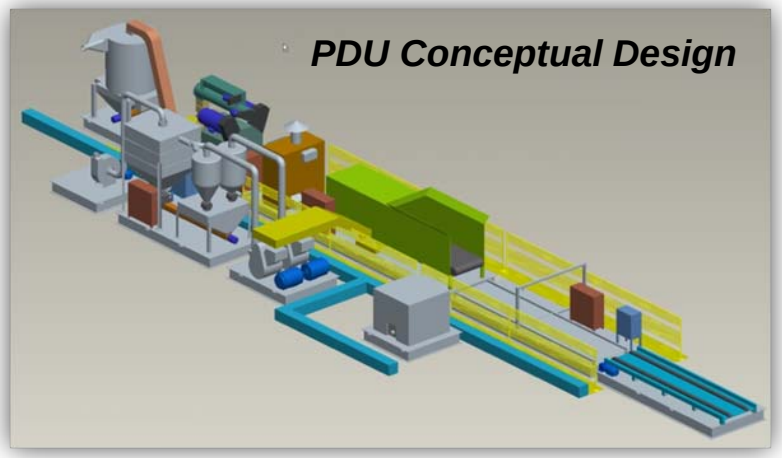
The Process Demonstration Unit Design

- PDU is a modular and reconfigurable biomass feedstock preprocessing system
- Design allows technologies to be tested in a fixed system for comparison and process improvement
- The baseline configuration will
  - utilize existing technologies such as grinders, dryers, pellet mills, dust collection systems, and handling equipment
  - Allow equipment swapping or operate independently from the balance of the system

PDU Portable Baseline Schematic (5 ton/hr)







PDU Modular Concept

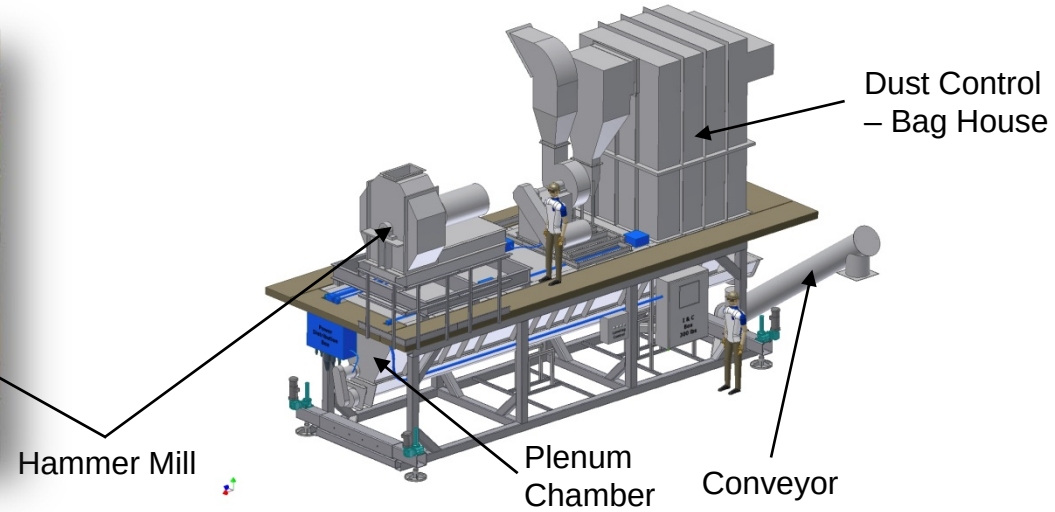
- Module 1 (Decomposition) – Stage I grinding (shredding)
- Module 2 (Grinding) – Stage II grinding (hammer mill)
- Module 3 (Drying) – Dryer for moisture reduction
- Module 4 (Densification) – Pelleting or other densification processes
- Controls, power, instrumentation, and safety systems – integrated operation through a control trailer.
- Modules are portable allowing for deployment in any location with adequate space and available utilities

Module 1 – Decomposition

- Input conveyor, weigh belt, and de-stringer for baled material
- Size reduction for bale/bulk material, target < 2 inches
- Output conveyor to move material to dryer or stage II grinder (hammer mill)

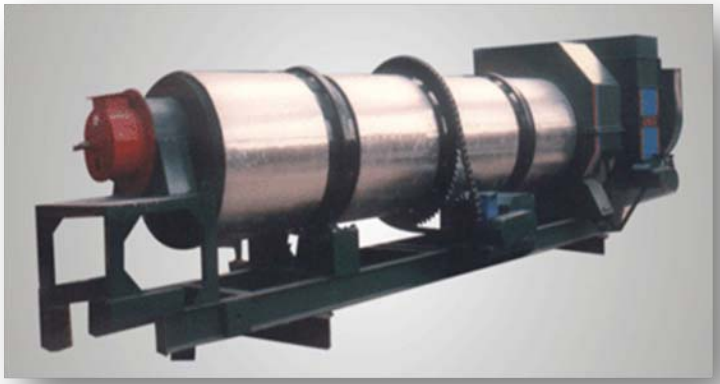
Module 2 – Grinding

- Size reduction to final densification particle size < ¼ inch.
  - Hammer mill mounted on a plenum chamber for dust collection/control
- Dust and fines collected at each module and returned to system or filtered
  - Equipment can be moved to other modules
  - Components: blower, bag house, air locks and plenum chamber



Module 3 – Drying

- Three pass rotating drum, variable heat furnace, variable blower, cyclone separator, and pneumatic conveyance
- Drying is not required for all materials thus feed stream can be diverted
- Oversized pneumatic transfer system for various operation modes
- The drum allows the dryer to operate as a single pass flash dryer or cycled for optimum end moisture



Module 4 – Densification

- Densification and conditioning converts ground material into > 40 lb/ft^3 product
- Base system includes pellet mill; can substitute cubers or briquetters
- Metering bin controls feeding of ground material into other modules
- Cooler improves quality and durability of product

Metering Bin

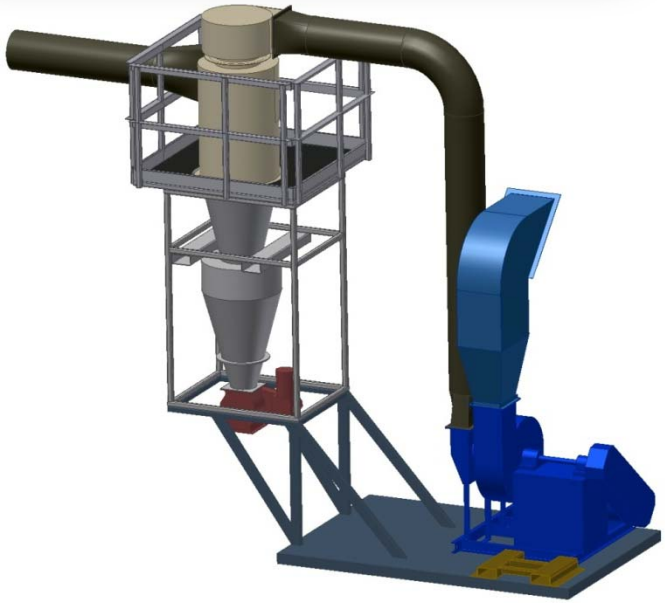
Steam Conditioning

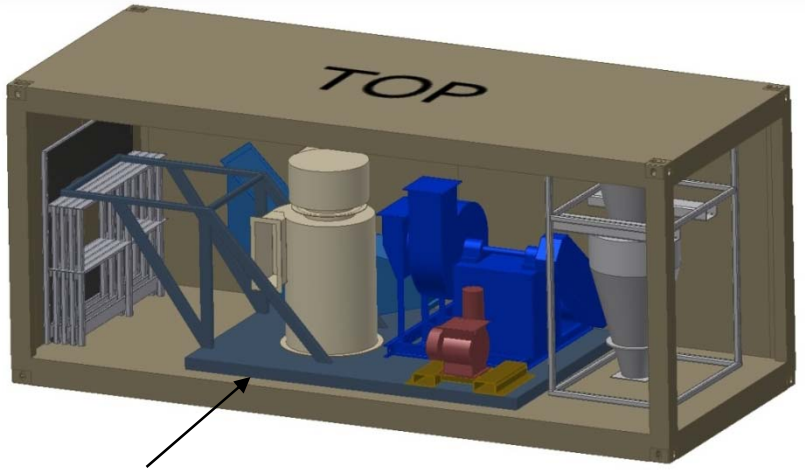
Pellet Mill

Cooler

Pneumatic Conveyance Setup and Packaged

Clam shell cargo container





Cyclone components disassembled and stored in a cargo container

Motor Control Center in Cargo Container

Control Trailer

Operator work station in main body

Control cabinets in front section

Conceptual Equipment Examples

- **Roller Forging Mill:**
  - low energy process, larger particle input
- **Thermal Treating:**
  - slow heating in a low/no oxygen atmosphere for more friable and low moisture material
- High Energy Kinetic/Impact Processing:
  - high velocity impact milling to reduce particle size and removing moisture
- Extrusion Drying:
  - friction and compression energy to dry
- Fractionation and Volatiles Extraction:
  - material fractionation and lignin separation in solvent and high-shear extrusion

Bench-scale
Thermal Treating Unit

Bioenergy Depends on Feedstock