Advanced Feedstock Supply System

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Key Point

- Technologies exist to supply biomass for energy production, but they have limits
  - Cost, quantity, quality
- I’ll present a potential solution: biomass commoditization
Current State of Logistics

- There are a variety of lignocellulosic biomass sources that could be used for energy production
  - Unstable, bulky, heterogeneous (format and quality), poor flowability
    - Creates logistics challenges
- Current supply chain models generally situate the biorefinery near the feedstock resource ("Conventional")
  - Minimizes transport cost
- Example: Corn stover in Iowa
Example: 2012 Herbaceous (Corn Stover) Feedstock Design

- **Harvest and Collection**
  - Corn Crop
  - Standing Grain Crop

- **Farm/Field Gate**
  - Grain Harvest with Stripper/Picker Header
  - Windrow Condition
  - Square Bale Collection System
  - Collect and Roadside to Stack
  - Square Bale Stack

- **Preprocessing**
  - Switchgrass
  - Grain
  - Bad Bales
  - Rebale
  - No Protection
  - Plastic Wrap
  - Tarp
  - Shed
  - Dust Collection
  - Feed System
  - Biochemical Conversion

- **Storage**
  - Unstack and Load
  - Transport
  - Receiving
  - Unload & Stac
  - Handling from Queuing Preprocessing
  - Preprocessing (including moisture adjustment)
  - Dust Collection
  - Even Flow

- **Transportation**
  - Bale Disposal (Compost or Burn)
  - Broke / Off Spec Bales
  - Broken / Off Spec Bales
  - Twine
  - Twine Disposal

- **Handling and Queuing**
  - Storage
  - Feed Sytem
  - Low-Pressure Feed System
  - Thermochemical Conversion (Low Pressure)
  - High-Pressure Feed System
  - Thermochemical Conversion (High Pressure)

- **Storage System Clean Up**
  - Plastic Wrap Disposal
  - Tarp Clean Up / Repair / Store / Disposal
  - Plastic Wrap
  - Tarp

- **Even Flow**
  - Biochemical Conversion

- **Clean Up**
  - Tarp Clean Up / Repair / Store / Disposal
  - Plastic Wrap Disposal
  - Plastic Wrap
Cost Improvement Pathway (2007 $)

Target: $35/DM ton to support meeting ethanol production cost target
Limits of Conventional Systems

Risk

- Biorefinery is vulnerable to supply chain upsets
- The biomass resources available are limited
  - stranded resources
- Burden of variability is on biorefinery
- Limited opportunity to address quality
- Limits biorefinery size

*Key Challenge:* Biomass is not where it needs to be (dispersed, often remote) or what it needs to be (quality); **Cost**

*Potential solution:* Biomass commoditization
Uniform-Format Feedstocks

Commodity Vision for Infrastructure Compatibility

**Commodity Attributes**

- Standardized material formats are compatible with existing solid and liquid supply handling systems and infrastructures.
- Feedstock quality is assured through national and international standards.
- National market systems secure supply and demand in a sustainable way.
- Biomass feedstocks futures contracts are tradable on commodity exchanges.

Diagram of feedstock transportation and processing options:

- Woody Residues
- Round Wood and Woody Energy Crops
- Municipal Solid Wastes
- Wet Herbaceous Residues and Energy Crops
- Dry Herbaceous Residues and Energy Crops
- Shipping Terminal Elevator
- Depot
- 5-20 Miles
- 50-150 miles
- 150-300 miles
- Rail, Truck, or Barge
- Multiple Biorefineries
- Conversion (Biochemical or Thermochemical)
Vision and Mission Areas

Vision: Transform Raw Biomass into High-Density, Stable, Commodity Feedstocks

Mission Areas:
• Improve Biomass Quality and End-use Performance
• Improve Biomass Density, Stability and Infrastructure Compatibility
• Increase Accessible Biomass Quantities/Diversity and Supply Stability

Vision Constraints:
• Cost
• Sustainability/GHG
Conceptual Implementation of the Commodity Feedstocks Vision

**Production System**
Production/Harvest/Collection/Short-Term Storage

- Round Wood and Woody Energy Crops
- Woody Residues
- Solid Urban Residues and Municipal Solid Wastes
- Herbaceous Residues and Energy Crops
- Algae and Other Microcrops

**Preprocessing Depot**
Preconversion/Formulation/Stabilization/Densification

- Preconversion/Formulation
- Densification/Stabilization

**Terminal**
Aggregation/Blending/Upgrading/Long-Term Storage

- Liquid or Solid Depot
- Co-located liquid or solid preprocessing and densification of lignin cake

**Refinery**
Conversion/Utilization

- Liquid Terminal
- Solid Terminal
- Hydrolysis and Fermentation
- Combustion
- Gasification
- Refining
- Electricity
- Chemicals
- Heat & Steam
- Ethanol
- Liquid Fuels
Grand Challenges

1. Density and Stability

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

2. Conversion Performance

   - Grade A Feedstock
     - (Material the conversion process was developed around)
     - Commodity Attributes
       - On-spec quality
       - Uniform density
       - Consistent format
       - Stable
       - Reliable supply
       - Infrastructure compatible

   - Field Run Biomass
     - Upgrade
     - Manage
       - Moisture content
       - Ash
       - Sugar
     - Diverse
       - Format
       - Density
       - Compositional properties (does not meet conversion spec)
Addressing Challenges

- Iteration between field work, lab work, and analysis
- Partnerships with industry, academia, and other National Labs
One Research Tool: PDU

- Process Demonstration Unit (PDU) is a modular and reconfigurable biomass preprocessing system that is highly instrumented for data collection (depot)
- The design allows testing and comparing technologies in a fixed system
- Allows equipment to be swapped out or operated independently
- Modules are portable allowing deployment in any location with adequate space and available utilities
Examples of Improvement: Grinder Capacity/Efficiency

- Start: 17.6 DMT/hr
- Current: 31.2 DMT/hr
- Successes:
  - 77% increase in grinder capacity due to:
    - Improved grinder operation
    - Pneumatic conveyance
  - Improved understanding of particle size distribution

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

\[
y = 11.9669e^{-0.0618x}
\]
\[
y = 31.3152e^{-0.1102x}
\]
Addressing Near-term Barriers that Allow an Industry to Grow

**IMPROVE CONVERSION PERFORMANCE**

**Raw Biomass → Feedstock**
- Reduce feedstock variability (composition, moisture, physical and mechanical properties)
- Minimize carbohydrate losses
- Transform to feedstock classes and grades

**DEVELOP INFRASTRUCTURE-COMPATIBLE LOGISTICS SYSTEMS**

**Feedstock → Commodity Feedstocks**
- Develop harvest, collection, and storage systems optimized for biomass
- Network flexibility for both local and national markets
- Implement industrial scalability and efficiency from field to conversion infeed
- Couple to existing high-capacity solid/liquid infrastructure
- Transform to uniform handling formats

**MAXIMIZE GROSS AND FUNCTIONAL YIELD**

**Residues → Billion Ton**
- Scale up sustainable resource production to meet future demand

**Years 1-5**
- Achieve Grade A feedstock standards from field-run biomass resource

**Years 5-10**
- Upgrade and achieve absolute specifications (advanced feedstocks for advanced biofuels)

**Years 10+**
- Develop new customized feedstocks for optimized conversion

**Years 1-5**
- Develop infrastructure-compatible biomass-specific equipment/processes

**Years 5-10**
- Develop infrastructure-compatible biomass-specific equipment/processes that accept multiple resource types

**Years 10+**
- Optimize processes/infrastructure based on market drivers

**Years 5-10**
- Leverage/build on existing crop development and biotechnology from other agricultural industries

**Years 10+**
- Maximize sustainable biomass production/yield of multiple resource types
Contribution to $3/gal target: FSL 2017 Pathway

Feedstock Cost Challenge

Feedstock Quality Challenge

Approach

• 2015 – Validate a suite of advanced preprocessing systems
• 2017 – Implement advanced preprocessing within the $80/ton reactor throat target (Strategy: blending/formulation of low-cost resources)
• 2022 – Fully integrated advanced feedstock system for all resources (Strategy: fractionation/merchandizing feedstock intermediates to multiple markets/customers)
Getting There from Here

How do we transition from:

• Today’s vertically integrated supply systems
  – Designed around limited markets, specific feedstocks and conversion facilities, and a constrained supply radius

• To tomorrow’s commodity supply system
  – Designed around scaled-up, fully networked, commodity supply system infrastructures and markets

There is a need for R&D focus on addressing tomorrow’s barriers that have a positive impact on today’s biorefineries and supply systems