Switchgrass and Bioenergy Crop Logistics

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Acknowledgement
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Storage and Transportation Logistics

Scale of feedstock supply chain challenges

- Present Agricultural Grain Production (Corn, Wheat, Soybean).
  - Grain Supply Chain, 488 million tons (Bulk density 46 lb/ft$^3$, 775 kg/m$^3$)
    $\rightarrow$ 786 m yd$^3$ (570 m m$^3$)

- DOE Billion Ton Study
  - Agricultural Residues and Perennials, 802 million tons (730 m tonnes)
  - Forest Products, 368 million tons (335 m tonnes)
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Scale of Cellulosic feedstock supply chain (50 m gal refinery)

- Present Grain Ethanol Plant (50 Million Gals/year).
  - Assuming 2.8 gal/bu yield,
  - Grain Supply Chain, 0.5 million tons (Bulk density 46 lb/ft³)
    → 0.82 millions yd³ → 20000 trucks/year (25 ton/truck) → 56 trucks/day (25 ton/truck)

- Cellulosic Ethanol Plant (50 Million Gals/year).
  - Assuming 75 gal/ton yield,
  - Ethanol Supply Chain, 0.67 million tons
  - Assume 53 ft. truck filled to capacity (8ft x 9 ft. x 53 ft. = 141 yd³)

  - Raw Bulk density 3 lb/ft³
    → 444.5 million yd³ → 116000 trucks loads /year (6 ton/truck)

  - Bale density 10 lb/ft³
    → 133.3 million yd³ → 35 000 trucks/year (19 ton/truck)

  - Pellet density 40 lb/ft³
    → 33.3 million yd³ → 27 000 trucks/year (25 ton/truck)
Storage and Transportation Logistics

Biomass Harvest

Field Collection Logistics

Field and Satellite Storage

Feedstock Receiving

Delivery Logistics
Feedstock Supply Chain will require the harvest, handling, pre-treatment, transportation and storage of large quantities of low-density feedstock material

- Increases in feedstock value density should occur as early as possible in the supply chain.
- Energy efficient, cost effective, Increase efficiency of downstream processes.

- **Harvest Technologies**
  - Harvest Capacity and costs
  - Capital Investment costs, Flexibility of machinery use
  - Seasonal Labor requirements, Timeliness of operations

- **Transportation Distance and Costs**
  - Local Farm Storage, Satellite Storage Systems, Central Storage Systems
  - Transportation Logistics and Infrastructure
    - Field Transportation Logistics, Biorefinery Transportation Logistics, Regional Transportation and Infrastructure

- **Storage System**
  - Wet Storage vs. Dry Storage,
  - Preprocessing during storage (Increase Energy Density / Value)

- **Material Transfer**
  - Bulk Material System vs. Unit Operations System
Development of Feedstock Supply Chain

• **Producer Acceptance**
  • Technology adoption
    • adoption curve must be dramatically shifted
  • Risk management
  • Timeliness of operations
  • Demonstration of a viable feedstock supply chain
    • Scale consistent with farm operations
• **Sustainable Production Systems**
  • Soil Quality, Water Quality, Environmental Concerns (Public Perception)
Biomass Supply Chain Criteria

Feedstock Supply Chain will require the harvest, handling, pre-treatment, transportation and storage of large quantities of material

• Sufficient quantity to reduce supply risk to bio-refinery
  • Pre-processing to Uniform Commodity format
  • Seasonal and regional shortages (drought years?)
  • Transportation limitations

• Consistent quality of product
  • Development of standards for sampling and quality determination
  • Payment on Dry Matter basis “or” Clean Dry Matter Basis

• Timely Operations and Delivery
  • Harvest window, Storage time
  • Centralized storage vs. satellite storage vs. field storage

• Sustainable and Economically viable
  • Producer, Custom Operator or Intermediate business
  • Biorefinery

• Maximize Bulk and Energy Density as close to harvest as possible
  • Increase bulk density, reduce moisture content
  • Conversion as distributed as possible
Present Mechanical harvesting and logistics are sufficient
  • Scale and cost structure is very different to animal forage model?
    • Cost structure very different
    • Industrial scale supply chain verse agricultural supply chain
  • Total cost per ton and yields will be paramount and quality is low priority ?
    • Variable quality will increase bio-refinery capital costs
    • Inconsistent quality will most likely affect refinery efficiency
  • Moisture Content not important can be managed at field or by preprocessing ?
    • Max yield harvest window and regional climate may prevent field drying
    • Most pre-processing systems will still require significant storage periods
    • Transportation of water is lost opportunity
    • Biorefinery waste water management is a major cost
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Switchgrass Harvest and Storage

Timing and Frequency of Harvest
• Maximum Yields Occur for single harvest after anthesis
  • Harvest after killing frost could conserve nutrients
  • Single Harvest provides maximum yields
  • Delay of harvest until spring results in yield reductions of 20-40 % (Shinners et. Al, 2010, Adler et al 2006)

Harvest Methods
• Large Round Baler
  • Lower capital costs, slightly lower density
  • Capacity of approximately 10 ton/hr., requires 75-100 hp power unit
  • Truck capacity approximately 11 dry tons/truck load
• Large Square Baler
  • High capital costs, Density 10-12 lb/ft$^3$
  • Capacity of approximately 15 ton/hr., requires 180-200 hp power unit
  • Truck capacity approximately 21 dry tons/truck load
• Loafer/Stack Wagon
  • Low cost, low density
  • Lower power requirement
  • Short duration haul distances only
• Future Large Anaerobic Modules
  • Storage Loss
Switchgrass Harvest and Storage

Storage Methods

• **Large Round Bales**
  - In Buildings, DM losses 1- 4%
  - Under Tarp, DM losses 3- 10%
  - Exposed, DM losses 5- 13%

• **Large Square Baler**
  - In Buildings, DM losses 2- 8%
  - Under Tarp, DM losses 6- 25%
  - Exposed, DM losses 7- 39%

• **Anaerobic Storage**
  - Bulk Silo, Ag-Bag, and Bale Wrap (cost approx. $9/ton)
  - DM losses 1- 5%

Building Cost approx. $10-12 square ft.

Total Harvest and Storage Cost Approx. $14-$24 /ton (Kumar et al., 2007)
cenusa: Feedstock Logistics Objectives

• Broad Objectives
  ▪ Development of systems and strategies to enable economic harvest, transportation, and storage of perennial grass feedstock

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cenusa: Feedstock Logistics Objectives

- Objectives
  - Harvest
    - Improve the field drying rate of perennial grasses to enhance product quality and reduce losses.
    - Development of standardized packages/modules
    - Quantify/reduce energy expenditure.
cenusa: Feedstock Logistics Approach

• Harvest, Improving Field Drying:
  - Develop mechanisms and systems to increase the crops specific surface area to increase rate and extent of moisture egress from the plant during field drying
cenusa: Feedstock Logistics Approach

• Harvest, Standardized Packages/Modules:
  
  ▪ Develop systems to create large standardized modules of compacted biomass that serve as both storage and transport devices
    
    ▪ Investigate large round modules.
    ▪ Investigate large tube modules.
Program Area No. 3 Approach

• Harvest: Quantify/Reduce Energy Expenditures:
  ▪ Quantify and reduce energy of size-reduction at harvest
    ▪ Compare baling versus chopping.
    ▪ Compare size-reduction locations:
      ✓ In-field.
      ✓ Post-storage.
cenusa: Feedstock Logistics Objectives

• Objectives

  ▪ Storage

    ▪ Development and evaluation of densification, stabilization and storage technologies for reduction of feedstock supply chain costs.
    ▪ Quantify storage characteristics
    ▪ Comparison of dry and moist storage systems
cenusa: Feedstock Logistics Approach

- Storage Characteristics:
  - Comparison of storage systems to improve storage stability and reduction of feedstock supply chain costs.
    - Compare outdoor bale schemes:
      - Film wrapped, tube wrapped, tarped.
    - Investigate tube module storage of dry, chopped grass.
    - Investigate anaerobic storage of moist, chopped grass.
cenusa: Feedstock Logistics Objectives

- Objectives
  - Transportation and Logistics
    - Develop more efficient handling systems
    - Integrated feedstock supply chain and logistics cost analysis.
    - Evaluation of the effect of distribution of energy crop production by landscape position on harvest and logistical costs
cenusa: Feedstock Logistics Approach

• Logistics; More Efficient Handling Systems:
  ▪ Develop systems to create large standardized modules of compacted biomass that serve as both storage and transport devices
  ▪ Compare large-scale handling systems:
    ✅ Multi-bale loading.
    ✅ Module mover.
Program Area No. 3 Approach

- Logistics; Evaluate of feedstock supply chain logistics:
  - Develop models of interaction between producer demographics, scale, spatial distribution of material, and yield.
  - Evaluation of the effect of distribution of energy crop production by landscape position on harvest and logistical costs.
Program Area No. 3 Outcomes

• Provide a more energy-efficient and weather-independent method of harvest.

• Provide more energy- and cost-efficient logistics systems, yielding a more positive energy balance.

• Projection of minimum production scale that will be economical.

• Development of technology and recommendations for sustainable and cost effective feedstock supply chains

• Development of optimal systems for feedstock supply chains, including validation of standardized preprocessing systems for feedstock supply chains.