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Sustainable Production and Distribution of Bioenergy for the Central USA

Agro-ecosystem Approach to Sustainable Biofuels Production via the Pyrolysis-Biochar Platform (USDA-NIFA AFRI CAP) • Grant no. 2011-68005-30411

Switchgrass and Bioenergy Crop Logistics

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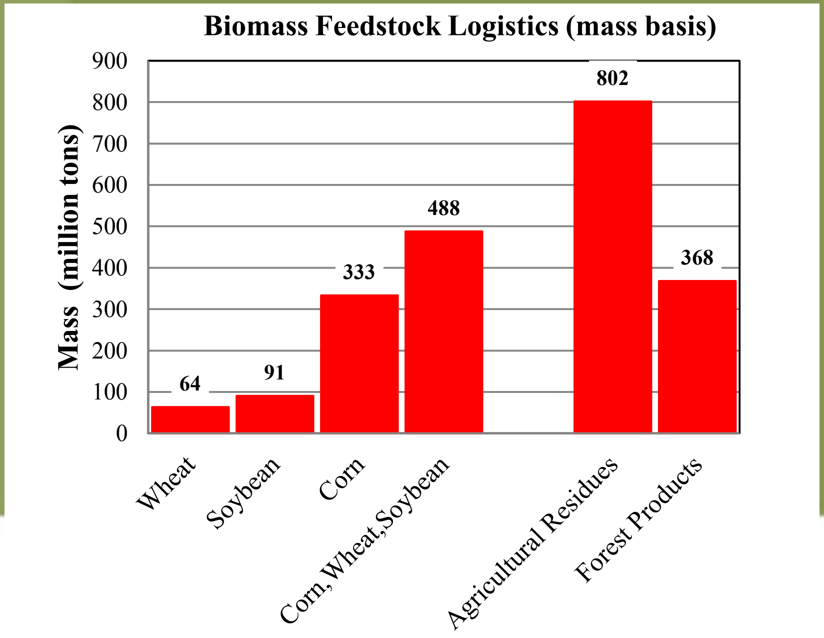
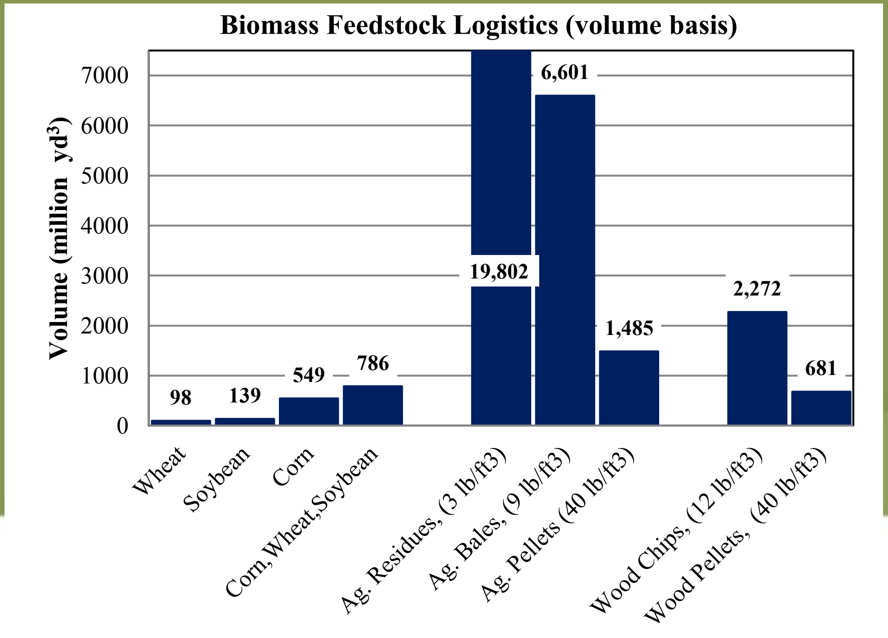
Storage and Transportation Logistics

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)
    → 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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Storage and Transportation Logistics

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/ft^3)

    → 0.82 millions yd^3 → 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 yd^3)
  - <u>Raw Bulk density 3 lb/ft^3</u>

    → 444.5 million yd^3 → 116000 trucks loads /year (6 ton/truck)
  - <u>Bale density 10 lb/ft^3</u>

    → 133.3 million yd^3 → 35 000 trucks/year (19 ton/truck)
  - <u>Pellet density 40 lb/ft^3</u>

    → 33.3 million yd^3 → 27 000 trucks/year (25 ton/truck)

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Storage and Transportation Logistics

Biomass Harvest

Field Collection Logistics

Field and Satellite Storage

Delivery Logistics

Feedstock Receiving

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Storage and Transportation 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.

- <u>Harvest Technologies</u>
  - Harvest Capacity and costs
  - Capital Investment costs, Flexibility of machinery use
  - Seasonal Labor requirements, Timeliness of operations
- <u>Transportation Distance and Costs</u>
  - Local Farm Storage, Satellite Storage Systems, Central Storage Systems
  - Transportation Logistics and Infrastructure
    - Field Transportation Logistics, Biorefinery Transportation Logistics, Regional Transportation and Infrastructure
- <u>Storage System</u>
  - Wet Storage vs. Dry Storage,
  - Preprocessing during storage (Increase Energy Density / Value)
- <u>Material Transfer</u>
  - Bulk Material System vs. Unit Operations System

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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

Biomass Supply Chain Assumptions

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

Storage and Transportation Logistics

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Feedstock Receiving

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 hip 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 hip 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

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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)

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cenusa: Feedstock Logistics Objectives

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

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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.

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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.

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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, tarpped.
    - Investigate tube module storage of dry, chopped grass.
    - Investigate anaerobic storage of moist, chopped grass.

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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.

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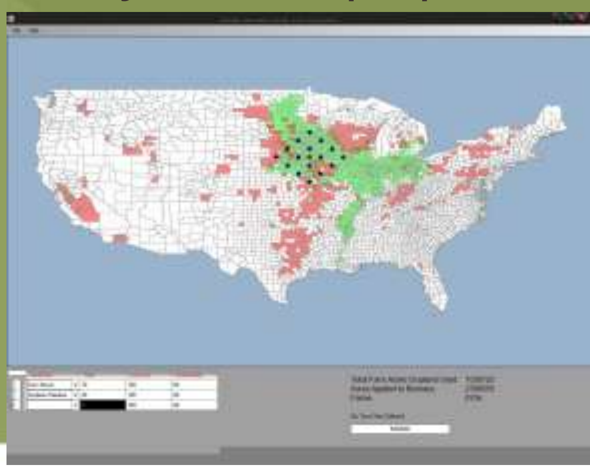
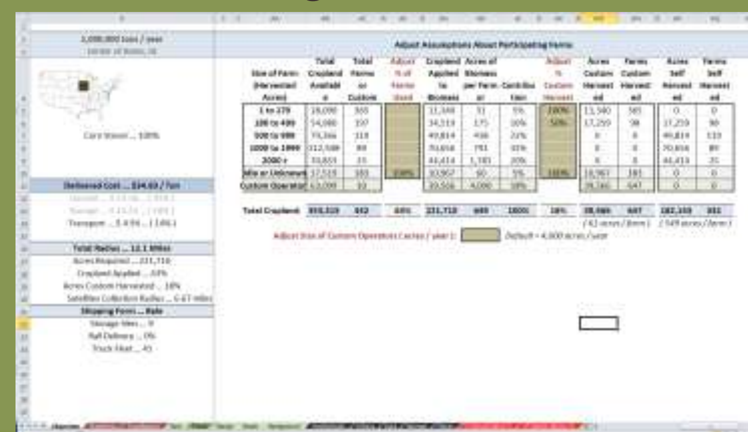
Program Area No. 3 Approach

- 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.





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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.

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