Millions of Acres for Dedicated Energy Crops: Farms, Ranches, or Plantations?

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February 12-13, 2008
Atlanta, GA
Cellulosic Ethanol

  - By 2022, 21 billion gallons of ethanol to be derived from non-cornstarch products (e.g. sugar or cellulose)
Feedstock for Cellulosic Ethanol

Billion Ton Biomass Study (DOE; USDA 2005)

– One billion dry tons from agricultural lands
  • sustainably collectable biomass and continue to meet food, feed and export demands  (p. 38)
Land for Dedicated Energy Crops

• DOE; USDA 2005
  – 55 million acres of cropland, idle cropland, and cropland pasture

• English et al. 2006
  – Switchgrass could be established on more than 100 million acres
Feedstock Acres

- 21 billion gallons (2007 Energy Act)
- 90 gallons per ton (DOE NREL goal)
- 3 - 7 dry tons per acre
- 33 - 78 million acres
- In 2007 US farmers planted
  - 60 million acres of wheat
  - 64 million acres of soybeans
  - 94 million acres of corn
Feedstock Production, Harvest, Storage, Transportation Challenges

• Unlike corn grain, harvest, storage, transportation, marketing, and risk management infrastructure does not exist
  – Spot markets work fine for corn grain
  – Spot markets don’t exist for switchgrass

• Continuous year-round flow of material to biorefinery

• Substantial investment required in harvest machines

• Large quantity of bulky material
Harvest Costs

(45-65 % of “Farm Gate” Production Costs)

Estimated Cost ($/dry ton)

Two-month Harvest Season

- Harvest: 33
- Field Cost: 8
- Land Rent: 10

Eight-month Harvest Season

- Harvest: 16
- Field Cost: 9
- Land Rent: 11
What Industry Structure

• Perennial grass

• After establishment year, very little annual maintenance required
  – One trip to broadcast fertilizer
  – Harvest

• Cost components:
  – Land
  – Establishment
  – Fertilizer
  – Harvest

• Structure likely to be determined by the most efficient harvest, storage and transportation system
Objective

- Determine the most efficient harvest system for a dedicated energy perennial grass such as switchgrass
  - 21 billion gallons (2007 Energy Act)
  - 3 - 7 dry tons per acre
  - 33 - 78 million acres
What Harvest System

• It depends on whether the processing system prefers
  – dry versus wet
  – loose versus dense

• It depends upon which cellulose processing technology “wins”
  – enzymatic hydrolysis
  – acid hydrolysis
  – gasification
  – gasification-fermentation
  – liquefaction
  – mixalco
Assumption For Discussion

Purposes

• Biorefinery uses the Oklahoma State University-University of Oklahoma-Coskata Gasification Bio-fermentation Process
Gasification Bio-fermentation

• Gasification - feedstock converted to synthesis gas
  — "dry" feedstock is preferred

• Bio-fermentation - synthesis gas converted into ethanol and other products
  — "…more than 100 gal / dry ton…"

• DOE, NREL enzymatic fermentation
  — goal of 90 gal / dry ton
Gasification Bio-fermentation

• Gasify dry feedstocks
• Gasification could use a variety of feedstocks
  – Switchgrass; miscanthus; corn stover; bagasse

(Note: technology remains unproven)
Quantity of Feedstock Required for a 4,000 tons per day Biorefinery

- 1,400,000 tons of biomass per year
- 350 days of operation per year
- 17 dry tons per truck
- 235 trucks per day
- 24 hours per day
- 9.8 trucks per hour
Quantity of Feedstock Required for a 4,000 tons per day Biorefinery

- 1,400,000 tons / y / biorefinery
- 470,000 (3 t/a) to 200,000 (7 t/a) acres
- 126 million gal / y / biorefinery (90 gal/t)
- 167 biorefineries to produce 21 billion gal / y (33 - 78 million acres)
Which Harvest Method?

• Current forage harvest systems
  – Small bales
  – Large cylindrical solid bales
  – Large rectangular solid bales
  – Loose chop
  – Cotton module systems
  – Silage systems

• Collect for field storage and transport substantial distances

• For large volume, and current forage harvest technologies, large rectangular solid bales is the least-cost system for harvesting biomass from perennial grasses in the Western Plains
Bale
Collect Bales and Stack for Field Storage
How Would Harvest be Managed?

- Harvest Costs
  45-65% of “Farm Gate” Production Costs
Experience from Custom Grain Harvest Companies (Great Plains)

- A substantial quantity of the grain in the Great Plains is Harvested by Custom Harvest Companies

  - Acres Harvested per Year  
  - Number of Combines  
  - Number of Trucks  
  - Number of Employees  

  Average
  - 28,049
  - 4.1
  - 6.3
  - 10.3

(Source: Kastens and Dhuyvetter, 2006)
Conceptual Coordinated Harvest System for Switchgrass

- Mowers
- Rakes
- Balers
- Tractors
- Field Stacker
- Workers

(Source: Thorsell et al.)
Model

- Multi-region, multi-period, mixed integer mathematical programming model

- Cropland
  - Conversion to Switchgrass
Economic Modeling

• determine the cost to produce, harvest, store, and transport a flow of biomass from perennial grasses produced in the Great Plains to an optimally located and sized biorefinery
Number of Harvest Machines Endogenously Determined

• Large rectangular solid bales
• Field workday distributions built from historical weather data (Mesonet system)
  – Mowing days
  – Raking, baling, stacking days
• Single harvest per year
  – 8 month harvest window (Jul – Feb)
• 2,000 dry tons per day
Switchgrass Expected Harvestable Yield (tons/acre)

expected yield 6.5 to 3.75 t/a depending on county and month of harvest
Switchgrass harvested per month for both a two- and eight-month harvest season to provide a flow of feedstock to a 2,000 dry tons per day biorefinery.
Estimated number of harvest machines for two- and eight-month harvest season to provide a flow of 2,000 t/day
Average investment in harvest machines for two- and eight-month harvest season to provide a flow of 2,000 t/day

- Two-month Harvest Season: $26,725,919
- Eight-month Harvest Season: $10,777,162
Estimated number of acres harvested per year per raking, baling, stacking harvest unit for two- and eight-month harvest season to provide a flow of 2,000 t/day.
“Farm Gate” Costs
(45-65 % for Harvest)
What do the Models Tell Us?

- Significant cost economies associated with harvest machines
- Harvest would extend over as many months as permitted by weather, feedstock sources, and policy
- Market forces would exploit the economies of size associated with harvest machines
  - independent harvest companies
  - wholly owned subsidiaries of biorefineries
Industry Structure

• Production characteristics and harvest cost economies more similar to U.S. timber production than to U.S. grain, oilseed, and fiber production

• Market forces may drive the structure toward vertical integration

• Feedstock production, harvest, and transportation may be centrally managed and coordinated

• Public policy that restricts business ties between feedstock production and feedstock processing is likely to hinder the development of a cellulosic biomass biorefinery industry
Quantity of Feedstock Required for a 4,000 tons per day Biorefinery

- 1,400,000 tons / y / biorefinery
- 470,000 (3 t/a) to 200,000 (7 t/a) acres
Possible Arrangements to Insure a Reliable Flow of Feedstock

• Acquire Land

• Long-term land leases similar to Conservation Reserve Program

• Contract with individual growers

• Contract with a group of growers via cooperative arrangement
Additional Challenges

• Risk management
  – Feedstock yield variability
  – Fire of standing and stored switchgrass

• 55 million acres of cropland, idle cropland, and cropland pasture identified in the billion ton study are widely dispersed

• The grain-ethanol program has increased the cost of inputs (land, fertilizer, machinery) required to produce switchgrass

• Discover, develop, design, and demonstrate an economically competitive biorefinery technology

• Build a **profitable business model**