Biofuel Supply Chain Challenges and Analysis

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Objectives of Research

- Identify current biofuel supply chain challenges.
  - Ethanol can only be sustainable if it is cost competitive

- Performed cost analysis of ethanol production using switchgrass
  - Performed deep dive into supply chain issues specific to switchgrass
Growth in Ethanol Fuel Production

- **Ethanol Production**

![U.S. Ethanol Production graph](source: U.S. DoE, Alternative Fuels & Advanced Vehicle Center)

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Biofuel Supply Chain

- **Overview of Biofuel Supply Chain**
  - Feedstock Production → Feedstock Logistics → Biofuels Production → Biofuels Distribution → Biofuels Enduse
  - Choosing which feedstock to grow
  - Harvesting
  - Storage
  - Preprocessing
  - Delivery
  - Conversion of feedstock into biofuel
  - Delivery to the mixing stations
  - Blend with fossil fuels
  - Serving end customers
Biofuel SC Challenges

- **Feedstock Production Challenges**
  - Cost reduction
    - Improvement of yield
    - Inexpensive cultivation techniques
  - Sustainability
    - Environmental implication
    - Net energy balance
    - Improvement of yield
  - New feedstock
    - Behavioral inertia of farmers
    - Cropland availability

- **Feedstock Logistics Challenges**
  - Stable Supply
    - Seasonality of harvest
    - Fluctuation of yield
    - Crop rotation
  - Design of network
    - Network of storage facilities
    - New delivery schemes
  - Preprocessing
    - Density-cost tradeoff
Biofuel SC Challenges

❖ Biofuel Production Challenges

- Conversion yield
- Co-products
- Benchmark

- Research enzymes and bacteria
- Biodegradable plastic from switchgrass
- Research thermal breakdown of materials
- High protein animal feed from corn
- Developing advanced catalysts
- Best practices of related industries

❖ Biofuel Distribution Challenges

- Geographical dislocation of supply and demand
- Delivery Capacity
Biofuel SC Challenges

- **Biofuel Enduse Challenges**
  - Meeting growing demand
    - Forecast of future demand
    - Assessment of impact of higher yield
  - Increasing blend
    - Chemical stability
    - Possible corrosion

Diversity of Feedstock

- **Ethanol Feedstock**
  - Virgin Grain: Corn, Wheat, Sorghum
  - Non-grain: Sugarcane, Sweet Potato, Switchgrass
  - Non-virgin (Recycled): Crop residue, Wood residue

Monosaccharide (Sugars) → Fermentation → Ethanol
Diversity of Feedstock

- Yield of biofuel from each feedstock

Ethanol Yield (L/ha)

Switchgrass Ethanol SC Challenges

- Switchgrass Production Issues
  - Dislocation of available cropland and cropland with high switchgrass yield

- Cropland available for switchgrass production
- Cropland with high switchgrass yield

Source: Brown, L. Plan B 2.0: Rescuing a Planet Under Stress and a Civilization in Trouble
Source for Switchgrass: Sokhansanj et al. (2009), Schmer et al. (2007)

Source: U.S. Department of Agriculture
Source: Sungrant Bioweb
Cost Analysis of Switchgrass Ethanol

- Cost analysis of harvesting and preprocessing options
  - Combinations of preprocessing and plant size
    - Preprocessing: Bailing (No preprocessing), Grinding, Pelletizing
    - Plant Size: Small (2000 Mg/day), Large (5000 Mg/day)

- Combined method: lowest transportation costs
  - Within 22 miles → grind switchgrass
  - Over 22 miles → pelletize switchgrass
Cost Analysis of Switchgrass Ethanol

<table>
<thead>
<tr>
<th>Supply Chain Stages</th>
<th>Details</th>
<th>Cost /Gallon</th>
<th>Cost /Gallon</th>
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<th>Cost /Gallon</th>
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<td>Pelletizing</td>
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<td>$0.796</td>
<td>$0.816</td>
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</table>

$240,000 Annual Savings!!

Cost to Produce Cellulosic Ethanol $2.200
Cost to Transport Ethanol (1500 Miles, from South Dakota to SFC or NYC) $0.837
Subtotal (from cropland to refinery) $0.796 $0.818
Total Costs $/ Gal $3.833 $3.854

Delivered cost of switchgrass ethanol

- Avg. U.S. gasoline price = $2.864 (all states)
  - On average 23% of this price is taxes

→ Switchgrass ethanol is not yet economically sustainable!
Conclusion

❖ Most urgent supply chain issues
  ◼ Biofuel cost
    ◼ Still requires government subsidy
  ◼ Farmers’ resistance to new feedstocks
    ◼ Must be solved to improve cost competitiveness
  ◼ Delivery capacity
    ◼ Shortage of delivery capacity would increase landed cost of biofuel

❖ Tradeoff
  ◼ High yield cropland ↔ Land cost
  ◼ Feedstock density ↔ Low cost
  ◼ Size of refinery ↔ Shipping cost to refinery

Thank You!
Biofuel SC Challenges

**Feedstock Production Challenges**
- Cost reduction
  - Improvement of yield
- Sustainability
  - Assessment of environmental implication and net carbon reduction
  - Net energy balance
  - Improvements in farming techniques to increase yield
- Adoption of new feedstocks
  - Behavioral inertia of farmers
  - Cropland availability

**Biofuel Production Challenges**
- Increasing conversion yield
  - How to reduce ‘recalcitrance’ (In the case of cellulosic ethanol)
  - Improving understanding of thermal breakdown of materials
  - Improving knowledge of microbes and enzymes
- Development of valuable co-products
  - e.g. Biodegradable plastic from switchgrass
- Leverage best practices of related industries
  - Petroleum refining, chemical manufacturing, and bioengineering
### Biofuel SC Challenges

#### Feedstock Logistics Challenges
- Stable feedstock supply
  - Seasonality of feedstock harvest & Quality degradation over time
  - Annual fluctuation of yield
  - Crop rotation
- Design of logistics network
  - Number of storage facilities & their network
  - Inventing new ways of delivery
- Preprocessing
  - Tradeoff of feedstock density vs. cost

#### Biofuel Distribution Challenges
- Geographical dislocation of supply and demand
  - Biofuels are currently refined near crop location, typically rural, then shipped to where the demand is
- Delivery Capacity
  - Not enough ethanol rail cars and hazmat drivers.
  - Not enough blending stations and transportation capacity
  - Possibility of using pipeline to deliver ethanol
Biofuel SC Challenges

- **Biofuel Enduse Challenges**
  - Matching supply and demand
    - Adoption of E85 compatible engines will require much more ethanol and capacity to transport ethanol compared to today
  - Increasing biofuel blend
    - Chemical stability during transportation
    - Possible corrosion