Estimating and Comparing Alternative Ethanol Processes and Feedstock Choices

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Overview

• Background
• Objectives
• Data & Methods
• Operational Assumptions
• Results & Conclusions
Background

- Grain Based Ethanol – Out of Favor with Some
- Cellulosic Ethanol Feedstocks
  - Non-competitive with food supply chain
  - Sufficient crop density
    - Minimize transportation costs
  - Maximize energy yield
  - Catch 22: most productive cropland is most competitive
    - May be economically prohibitive for biorefinery
  - “Marginal” growing areas may be better suited
Background

• Early Studies Identified Switchgrass
  - Led by Oak Ridge National Laboratory in 1990s

• Subsequent Economic Research Centered Around Switchgrass
  - USDA (De La Torre Ugarte et al, 2003)
  - University of Tennesee (English et al, 2006)
  - Oklahoma Sate University (Mapemba et al, 2007; Epplin et al, 2007)
  - Additional Research: Iowa State, University of Nebraska

• Other Feedstocks: Texas A&M University, University of Florida, Louisiana State University
Objectives

• Estimate Delivered Cost of Alternative Feedstock Mixes

• Estimate the Total Cost of Producing Ethanol Across Alternative Production Processes
  – Grain ethanol process
  – Cellulosic ethanol – MixAlco process
  – Brazilian ethanol process
Data

• Feedstock Production
  – Texas A&M Agronomists
  – Grower Panel

• Ethanol Production Processes
  – Grain process: Bryan & Bryan International
  – Cellulosic MixAlco process: Lau dissertation
  – Brazilian process: Brazilian industry representatives

• Historical Prices
  – NASS, DOE-EIA, FAPRI, Hart Energy

• Price & Inflation Forecasts: FAPRI
Methods

• Feedstock Production Model
  - Partial budget analysis
  - Monte Carlo simulation
  - Estimates delivered cost for alternative feedstock mixes
    - Two stage contract: Fixed minimum contract price per acre & additional per unit payment on actual yield
    - Harvest & transportation cost

• Ethanol Processing Model
  - Biorefinery Monte Carlo simulation
  - Maintains standard accounting relationships to estimate financial performance
  - Estimates total processing cost across alternative production processes and feedstock mixes
## Operational Assumptions: Grain Process

### Grain Ethanol
- **Proposed Capital Cost**: $2.25/gallon of ethanol
- **Ethanol Processing Costs**: $0.61/gallon of ethanol

### Grain Ethanol yield
- **Corn**: 2.75 gallons/bushel
- **Sorghum**: 2.75 gallons/bushel

### DDGs yield
- **Pounds/bushel**: 18.00

### Local Basis
- **Corn**: 0.05 $/bushel
- **Sorghum**: 0.15 $/bushel
- **Denaturant added**: 0.05 fraction
# Operational Assumptions: Cellulosic Process

**Cellulosic Ethanol**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed Capital Cost $/gallon of ethanol</td>
<td>0.63</td>
</tr>
<tr>
<td>Percent Dry Matter</td>
<td></td>
</tr>
<tr>
<td>Sweet Sorghum fraction</td>
<td>0.30</td>
</tr>
<tr>
<td>Sweet Sorghum Hay fraction</td>
<td>0.85</td>
</tr>
<tr>
<td>Sweet Sorghum HB fraction</td>
<td>0.40</td>
</tr>
<tr>
<td>Sugarcane fraction</td>
<td>0.33</td>
</tr>
<tr>
<td>Ethanol Processing Costs $/gallon of ethanol</td>
<td>1.25</td>
</tr>
</tbody>
</table>

**Cellulosic Ethanol Yield**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield for Contracting Acres gallons/ton of dry matte</td>
<td>90.00</td>
</tr>
<tr>
<td>Yield Parameters for Production</td>
<td></td>
</tr>
<tr>
<td>Min gallons/ton of dry matte</td>
<td>70.00</td>
</tr>
<tr>
<td>Med gallons/ton of dry matte</td>
<td>90.00</td>
</tr>
<tr>
<td>Max gallons/ton of dry matte</td>
<td>110.00</td>
</tr>
<tr>
<td>Denaturant added fraction</td>
<td>0.05</td>
</tr>
</tbody>
</table>
## Operational Assumptions: Brazilian Process

### Brazilian Ethanol
- **Proposed Capital Cost**: $6.07/gallon of ethanol
- **Percent Dry Matter**
  - Sweet Sorghum: 0.30 fraction
  - Sugarcane: 0.33 fraction
- **Brazilian Ethanol Yield**
  - Sweet Sorghum: 49.00 gallons/ton of dry matter
  - Sugarcane: 61.68 gallons/ton of dry matter
- **Cane Processing Costs**: $0.19/gallon of ethanol
- **Ethanol processing costs**: $0.38/gallon of ethanol

### Grain Ethanol Backup
- **Grain Ethanol yield**
  - Corn: 2.75 gallons/bushel
  - Sorghum: 2.75 gallons/bushel
- **DDGs yield**: 18.00 pounds/bushel
- **Ethanol processing costs**: $0.61/gallon of ethanol
- **Denaturant added**: 0.05 fraction
Cellulosic Feedstock Mixes

**Feedstock Mix 1**
- Sweet Sorghum Hay 2 months
- Sugarcane 6 months
- Sweet Sorghum 4 months

**Feedstock Mix 2**
- Sweet Sorghum HB 2 months
- Sugarcane 6 months
- Sweet Sorghum Hay 2 months

**Feedstock Mix 3**
- Sweet Sorghum 2 months
- Sweet Sorghum Hay 8 months
- Sweet Sorghum HB 2 months

**Feedstock Mix 4**
- Sweet Sorghum Hay 8 months
Brazilian Feedstock Mixes

Feedstock Mix 1
- Sweet Sorghum 4 months
- Corn or Sorghum 8 months

Feedstock Mix 2
- Sugarcane 6 months
- Corn or Sorghum 6 months

Feedstock Mix 3
- Sweet Sorghum 4 months
- Sugarcane 6 months
- Corn or Sorghum 2 months
## Delivered Feedstock Cost

<table>
<thead>
<tr>
<th>Feedstock Mix</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>$/bu</td>
<td>3.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>$/bu</td>
<td>3.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cellulosic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet Sorghum</td>
<td>$/ton dry matter</td>
<td>87</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>Sweet Sorghum Hay</td>
<td>$/ton dry matter</td>
<td>116</td>
<td>116</td>
<td>121</td>
</tr>
<tr>
<td>Sweet Sorghum HB</td>
<td>$/ton dry matter</td>
<td>-</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>$/ton dry matter</td>
<td>88</td>
<td>88</td>
<td>-</td>
</tr>
<tr>
<td><strong>Brazilian</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet Sorghum Billet</td>
<td>$/ton dry matter</td>
<td>89</td>
<td>-</td>
<td>89</td>
</tr>
<tr>
<td>Sugarcane Billet</td>
<td>$/ton dry matter</td>
<td>-</td>
<td>89</td>
<td>89</td>
</tr>
</tbody>
</table>
## Estimated Total Cost of Ethanol Production

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grain</strong></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>2.02</td>
</tr>
<tr>
<td>Sorghum</td>
<td>1.96</td>
</tr>
<tr>
<td><strong>Cellulosic</strong></td>
<td></td>
</tr>
<tr>
<td>Feedstock Mix 1</td>
<td>2.46</td>
</tr>
<tr>
<td>Feedstock Mix 2</td>
<td>2.44</td>
</tr>
<tr>
<td>Feedstock Mix 3</td>
<td>2.65</td>
</tr>
<tr>
<td>Feedstock Mix 4</td>
<td>2.67</td>
</tr>
<tr>
<td><strong>Brazilian</strong></td>
<td></td>
</tr>
<tr>
<td>Feedstock Mix 1</td>
<td>2.37</td>
</tr>
<tr>
<td>Feedstock Mix 2</td>
<td>2.32</td>
</tr>
<tr>
<td>Feedstock Mix 3</td>
<td>2.54</td>
</tr>
</tbody>
</table>
Grain Ethanol Sensitivity

Total Cost of Ethanol Production

<table>
<thead>
<tr>
<th>Grain Price, FOB</th>
<th>Corn $/gallon</th>
<th>Sorghum $/gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/bu</td>
<td>4.00</td>
<td>4.25</td>
</tr>
<tr>
<td></td>
<td>4.50</td>
<td>4.75</td>
</tr>
<tr>
<td></td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td>$/gallon</td>
<td>2.27</td>
<td>2.30</td>
</tr>
<tr>
<td></td>
<td>2.35</td>
<td>2.39</td>
</tr>
<tr>
<td></td>
<td>2.44</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>2.53</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>2.61</td>
<td>2.65</td>
</tr>
</tbody>
</table>

- Cellulosic process average: $2.56
- Brazilian process average: $2.41
Conclusions

• Delivered Prices of Non-Grain Feedstocks are Economically Prohibitive versus Baseline Price Estimates for Grain

• Of the Alternative Ethanol Processing Scenarios Analyzed, Grain Ethanol Remains the Most Economically Feasible

• The Brazilian Ethanol Process Ranks Second, Yet Becomes Competitive at $4.50 Grain Prices

• If the MixAlco Cellulosic Process Becomes Commercially Viable, it Becomes Competitive at $4.75-$5.00 Grain Prices
Thank You