Implications of Emerging Technology on the Ethanol Industry

Gary Lemme
Dean/Professor
College of Agriculture and Biological Science
South Dakota State University
### Recent Ethanol Industry Expansion

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biorefineries Online</td>
<td>54</td>
<td>56</td>
<td>61</td>
<td>68</td>
<td>72</td>
<td>81</td>
<td>95</td>
<td>110</td>
</tr>
<tr>
<td>Capacity (mgd)</td>
<td>1748.7</td>
<td>1921.9</td>
<td>2347.3</td>
<td>2706.8</td>
<td>3100.8</td>
<td>3643.7</td>
<td>4336.4</td>
<td>5493.4</td>
</tr>
</tbody>
</table>

### U.S. Ethanol Production Capacity by State

<table>
<thead>
<tr>
<th>State</th>
<th>Online</th>
<th>Under Construction/Expansion</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iowa</td>
<td>1701.5</td>
<td>1535</td>
<td>3236.5</td>
</tr>
<tr>
<td>Nebraska</td>
<td>655.5</td>
<td>965</td>
<td>1620.5</td>
</tr>
<tr>
<td>Illinois</td>
<td>831</td>
<td>341</td>
<td>1172</td>
</tr>
<tr>
<td>South Dakota</td>
<td>532</td>
<td>378</td>
<td>910</td>
</tr>
<tr>
<td>Minnesota</td>
<td>541.6</td>
<td>240.5</td>
<td>782.1</td>
</tr>
<tr>
<td>Indiana</td>
<td>102</td>
<td>551</td>
<td>653</td>
</tr>
<tr>
<td>Kansas</td>
<td>212.5</td>
<td>295</td>
<td>507.5</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>230</td>
<td>272</td>
<td>502</td>
</tr>
<tr>
<td>Texas</td>
<td>0</td>
<td>370</td>
<td>370</td>
</tr>
<tr>
<td>Ohio</td>
<td>3</td>
<td>330</td>
<td>333</td>
</tr>
<tr>
<td>Michigan</td>
<td>155</td>
<td>107</td>
<td>262</td>
</tr>
<tr>
<td>North Dakota</td>
<td>83.5</td>
<td>150</td>
<td>233.5</td>
</tr>
<tr>
<td>New York</td>
<td>0</td>
<td>164</td>
<td>164</td>
</tr>
<tr>
<td>Missouri</td>
<td>155</td>
<td>0</td>
<td>155</td>
</tr>
<tr>
<td>Oregon</td>
<td>0</td>
<td>143</td>
<td>143</td>
</tr>
<tr>
<td>Colorado</td>
<td>85</td>
<td>40</td>
<td>125</td>
</tr>
<tr>
<td>Tennessee</td>
<td>67</td>
<td>38</td>
<td>105</td>
</tr>
<tr>
<td>Georgia</td>
<td>0.4</td>
<td>100</td>
<td>100.4</td>
</tr>
<tr>
<td>California</td>
<td>68</td>
<td>0</td>
<td>68</td>
</tr>
<tr>
<td>Arizona</td>
<td>0</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Washington</td>
<td>0</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Kentucky</td>
<td>35.4</td>
<td>0</td>
<td>35.4</td>
</tr>
<tr>
<td>New Mexico</td>
<td>30</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Wyoming</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>5493.4</td>
<td>6129.5</td>
<td>11,622.9</td>
</tr>
</tbody>
</table>

Source: Renewable Fuels Association, January 2007
U.S. Ethanol Biorefinery Locations

- Biorefineries in production
- Biorefineries under construction

# of biorefineries: 110 as of January 1, 2007

Source: Renewable Fuels Association
Emerging Ethanol Technology

• **TIME LINE**
  – Current: Corn-based Dry Mill Production
  – Near future (1-3 years): Corn Ethanol with Oil Recovery
  – Intermediate Future (2-4 years): Corn Ethanol with Oil Recovery and Fiber Conversion to Ethanol
  – Distant Future (8-10 years): Biomass Conversion to Ethanol
Ethanol Industry

• **Rural Community Economic Development, 2006**
  - $41.1 billion gross output
  - 160,231 jobs
  - $2.7 billion new tax revenue

• **Producer ownership/investment**
  - Income diversification ($0.60 / gallon dividends)
  - Production integration & partnerships

• **National fuel security**
1 bushel corn grain =
- 2.8 gallons of ethanol
- 18 pounds dried distillers grains (DDGS)
- 0 pounds oil
- 18 pounds carbon dioxide

Yeast convert sugars to ethanol and CO$_2$
In equal amounts
Ethanol Dry Milling Process
Source: American Coalition for Ethanol

- Corn
  - Grind
  - Cook
    - Liquify
      - Saccharify
        - Enzymes
  - Fermentation
    - Bler
      - Distillation
        - Whole Stillage
          - Centrifugation
            - Thin Stillage
              - Evaporation
                - Distillers Solubles
            - Wet Grains
              - Dryer
                - Syrup
                  - Distillers Grains w/ Solubles
  - Dehydration
    - 190 Proof Ethanol
      - 200 Proof Ethanol
        - Product Storage
          - Denaturant
            - Fuel Ethanol
          - Distillers Dried Grains
# DDGS Feeding Recommendations

<table>
<thead>
<tr>
<th>Specie</th>
<th>Lbs. DDGS/HD/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef Cow</td>
<td>5-7</td>
</tr>
<tr>
<td>Beef Steer/Heifer &gt;500 lbs</td>
<td>3-4.5</td>
</tr>
<tr>
<td>Calves &lt; 500 lbs</td>
<td>2-3</td>
</tr>
<tr>
<td>Dairy Cows</td>
<td>5-10</td>
</tr>
<tr>
<td>Dairy Heifers</td>
<td>1-5</td>
</tr>
<tr>
<td>Swine nursery</td>
<td>0.1-0.5</td>
</tr>
<tr>
<td>Swine Grow-Finish</td>
<td>0.6-1.2</td>
</tr>
<tr>
<td>Sows &amp; Boars</td>
<td>0.8-3.2</td>
</tr>
<tr>
<td>Sheep Ewe</td>
<td>2</td>
</tr>
<tr>
<td>Sheep Lamb</td>
<td>0.5-1.1</td>
</tr>
<tr>
<td>Chicken Broilers</td>
<td>0.4</td>
</tr>
<tr>
<td>Chicken layers/peak season</td>
<td>0.022</td>
</tr>
<tr>
<td>Turkey Hens</td>
<td>0.035</td>
</tr>
</tbody>
</table>

[2006 North American Distillers Grains Consumption]

- Dairy 48%
- Beef 42%
- Poultry 3%
- Swine 9%

*Source: Commodity Specialists Co.*
Current South Dakota Usage of DDGS

- Beef = 404,750 T/YR
- Dairy = 201,913 T/YR
- Swine = 305,327 T/YR
- Sheep = 34,050 T/YR
- Poultry = 67,002 T/YR

65% of DDGS produced in SD could be consumed in SD
National 2007 DDGS Production

• **Situation**

5.5 billion gallons per year ethanol produced/2.8 gal/bu = 1.9 billion bushels corn consumed*18 lbs DDGS per bushel consumed = $3.5 \times 10^{10}$/2000 lbs/t = **17.65 million tons DDGS**

**Solution?**
Near Future Technology: Corn Ethanol with Oil Recovery

• Process
  – germ recovery (Fractionation of corn prior to fermentation)
  – Co-product oil separation (post-distillation oil capture)

• Impact
  – 1.5 lbs oil/bushel for biodiesel or food uses
  – New DDGS products (range cubes, lick tubs)
  – 4% higher protein DDGS

• Yield/bushel corn
  – 2.8 gallons ethanol
  – 15.5-16.5 lbs DDGS
  – 1.5 lbs oil
  – 18 pounds carbon dioxide
Intermediate Future Technology: Corn Ethanol with Oil Recovery and fiber converted to Ethanol

• Process
  – Up stream fractionation with germ recovery (fibers > fermentable sugars using cellulase enzymes & fermented to ethanol)
  – Hydrolyze DDGS with cellulase enzymes yield fermentable sugar for fermentation to ethanol
  – Thermal catalytic conversion to convert DDGS to sugars for ethanol

• Impact
  – 1.5 lbs oil/bushel for biodiesel or food uses
  – DDGS reduced by 2/3

• Yield/bushel corn
  – 3.4-3.6 gallons ethanol
  – 5-6 lbs DDGS
  – 1.5 lbs oil
  – 23-24 pounds carbon dioxide
“Rumpelstiltskin spins gold from straw”,
Grimm Brother

Cellulosic Ethanol

South Dakota State University
College of Agriculture & Biological Sciences
Distant Future (8-10 years): Biomass Conversion to Ethanol

• **Process**
  – Biomass feedstocks (1/3 cellulose, 1/3 hemicellulose, 1/3 lignin)
  – Developing Technology
    • (>80% cellulose & hemicellulose conversion required)
    • Biological conversion processes to sugars to ethanol
    • thermal kinetic conversion processes to sugars to ethanol

• **Impact**
  – No DDGS or feed materials
  – No oil produced

• **Yield/ton Biomass**
  – 90-100 gallons of ethanol
  – 600-650 lbs lignin (burned as boiler fuel)
  – 620-680 lbs CO₂
THE PRODUCTION OF ETHANOL FROM CELLULOSIC BIOMASS
Growing America’s:
Bioresnewable Energy

Ag residues
Corn stover (4 tons/acre/year)
Small grain straw (1 ton/acre/year)
Bioenergy Field

Energy Crops

• Perennial crops
• Grass crops (5 - 20 tons/year)
• Woody crops (10 tons/year)
• 1,000 gallons ethanol/acre
This study estimates the technical biomass resources currently available in the United States by county. It includes the following feedstock categories:

- Agricultural residues (crops and animal manure)
- Wood residues (forest, primary mill, secondary mill, and urban wood)
- Municipal discards (methane emissions from landfills and domestic wastewater treatment)
- Dedicated energy crops (on Conservation Reserve Program and Abandoned Mine Lands)
Challenges to Biomass Energy

- Developing a stable & sustainable feedstock supply
- Feedstock infrastructure
- Conversion efficiency hurdles
- Cost-competitiveness
Impacts Public Policy on Technology and Industry
Public Policy Issues facing Biorenewable Energy Industry

1. Effective & timely permitting processes
2. Infrastructure investment:
   roads, rails, water, capital
3. Environmental and transportation regulations/mandates on producers and consumers
4. Intergenerational farm transfer
5. Economic competitiveness
6. Workforce development:
   education system,
   vitality of communities
Adapting technology to grow rural America
Stewardship of natural resources while growing the economy (field to fuel tank to family analyses)
Emerging Ethanol Technology

**TIME LINE**
- Current:
  - Corn-based Dry Mill Production
- Near future (1-3 years):
  - Corn Ethanol with 1.5 lbs/bu Oil Recovery
- Intermediate Future (2-4 years):
  - Corn Ethanol with 1.5 lbs/bu Oil Recovery and Fiber Conversion to 0.8 gal/bu Ethanol
  - 2/3 reduction in DDGS
- Distant Future (8-10 years):
  - Biomass Conversion to 110 gal/t Ethanol
  - No DDGS; No oil
How much ethanol can SD produce from corn stover? (2004 data)

- 4.15 million acres corn @ 130 bu/a
- 539.5 million bu corn = 15.1 million tons corn & 15.1 million tons stover (1:1 mass ratio)
- 45% stover removal (sustains tilth) = 6.8 million tons
- 680 million gallons ethanol/year produced (100 gal ethanol/ton stover)
- Plus {1.51 billion gallons ethanol from grain} (2.8 gal/bu grain)