Ethanol (EtOH) & Other Renewables
IAEE – Houston Chapter
June 14, 2007
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Key Topics

US Ethanol Supply & Demand
- Forces Driving Ethanol / Biofuels
- Current Situation
- Possible Future Scenarios
- Increase in Renewable Fuels Standard Mandate?

Economics
- Ethanol Relative Production Costs --- Corn, Sugar Cane, Cellulosic
- Pro Forma Economics – Corn Dry Mill

Some Abbreviations and Terminology
- RFS = Renewable Fuels Standard
- EtOH = Ethanol
- BD = Biodiesel (B100 = 100%, B20 = 20% with refinery diesel)
- RFG = Reformulated Gasoline used in 9-12 areas of US
- MTBE = Oxygenate formerly used in RFG
- RBOB = Reformulated Gasoline Blending Component
  Before Oxygenate Blending (EtOH is the Oxygenate)
Supply & Demand - Forces Driving US Renewable Fuels

Drivers
- “Renewable”
- Energy Prices / “Security”
- GHGs
- Loss of MTBE
- Blending Properties

RFS Expansion?
- RFS mandate *likely* increases to 11-13 BGPY in 2012, 15 BGPY in 2015
- 2007 Farm Bill Re-authorization
- Democrats to push for more “energy independence” & force key Republicans to support RFS increase
  - Sen. Bingaman’s bill = 35 BGPY
- Some key energy committee members don’t support EtOH
- NPRA trying to slow down RFS and reduce subsidies
- Other industries are objecting

Government Support
- Mandates
- Tax Incentives

- Bioethanol
- Biobutanol
- Biodiesel

- Good ROI
- Rural Jobs
- Fuel Diversification
- “Lower Imports”
Corn Cost Backlash?
Supply & Demand – Possible Scenarios

- US capacity exceeds current RFS demand thru 2012
- Subsidies / tariffs --- overbuilding?
- New plant proposals driven by EtOH producers betting on RFS increase
- Increased capital costs will cause some proposals to be cancelled
- Sen. Bingaman’s bill = 35 BG PY
- Petrobras JV in Japan and possible increase of EtOH in mogas from 3% to 10% might reduce US avails
- India, China, Canada, Thailand, EtOH programs add complexity
Supply & Demand - Can US Market Absorb More Ethanol?

- 17 BGPY RFS requires ~350 MBD E85
- “Planting” State of Iowa = 600 MBD
- EIA says sufficient E85 vehicles will be built --- but by when?

E85 has huge potential, but - - -
- About 30% lower mpg – Consumers?
- Cannot be shipped in pipelines
- Only about 3% of U.S. cars can currently use it (5% by 2015)

- Domestic auto companies will support
- Significant investment required to make available to consumers
- EPAct 2005 incentive to gas stations

% of US Mogas in 2015
- RFS = 490 MBD = 5%
- 15 BGY = 980 MBD = 10%
- 35 BGY = 2.3 MMBD = 23%
Supply & Demand - Can US Market Absorb Renewables?

% Gasoline Demand

- Can’t quickly turn over auto fleet to E85 “Flex-Fuel”
- Logistics limit E85 availability
- Unlikely all 35 BGY renewable is EtOH into mogas
- Resistance to EtOH is Increasing
- Biodiesel helps and has advantages
- Emerging biobutanol is another possibility & “better” than EtOH

% Gasoline & Distillate Demand

- Likely that significant incentives must continue
Supply & Demand – Domestic & Import Supply Sources

Imports
- CBI imports limited to 7% of US production; never at this level
- Some CBI imports from Brazil
- Largest imports from Brazil - - - If arb is open
- Arb open with high mogas prices
- Current tariff 54 cpg + 2.5% duty
- 2006 imports about 666 MM Gal or 15% of RFS demand

Domestic Supply
- Current US capacity 5.8 BGPY
- Forecasted in 2010 10-11 BGPY

Huge majority of demand on East, Gulf & West Coasts
<table>
<thead>
<tr>
<th>Feed</th>
<th>Yield – Gal / Acre</th>
<th>Technology Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Mill Corn</td>
<td>400</td>
<td>Well Known</td>
</tr>
<tr>
<td>Sugar Cane</td>
<td>725</td>
<td>Well Known</td>
</tr>
<tr>
<td>Cellulosic – Corn Stover</td>
<td>800-1,200</td>
<td>? ? ?</td>
</tr>
<tr>
<td>Cellulosic – Switch Grass</td>
<td>~1,000</td>
<td>? ? ?</td>
</tr>
</tbody>
</table>

From a land use and food cost perspective . . .

- EtOH BTU / gal = 2/3 gasoline BTU / gal
- 1 MM acres of corn = 17 MBD gasoline and
- “One Iowa” = 600 MBD gasoline
- Current RFS = 490 MBD gasoline
# Economics - Comparison of Ethanol Processes

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sugar Cane</th>
<th>Dry Mill Corn</th>
<th>Wet Mill Corn</th>
<th>Cellulosic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed Cost</td>
<td>Higher</td>
<td>Lower</td>
<td>Lower</td>
<td>Lowest</td>
</tr>
<tr>
<td>Energy</td>
<td>Can be Low</td>
<td>High Nat Gas</td>
<td>High Nat Gas</td>
<td>Highest</td>
</tr>
<tr>
<td>Other Opex</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>1.5x Dry Mill</td>
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<tr>
<td>Capex</td>
<td>High</td>
<td>&lt; Wet Mill</td>
<td>High</td>
<td>4x Dry Mill</td>
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<tr>
<td>Technology</td>
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<td>Proven</td>
<td>Proven</td>
<td>Unproven</td>
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<tr>
<td>Difficulty</td>
<td>Easy</td>
<td>Difficult</td>
<td>Difficult</td>
<td>“Termites”</td>
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<tr>
<td>Co-products</td>
<td>None</td>
<td>High Value</td>
<td>High Value*</td>
<td>Maybe</td>
</tr>
</tbody>
</table>

- Despite uncertainty, Shell, Goldman Sachs, Abengoa pursuing cellulosic
- Economic analysis based on Dry Mill process that dominates in US
Cost Comparison – Dry Mill Ethanol Manufacturing Cost

“Avg” Corn Futures June 2007 ~$4.00

Platts Average 2007 YTD June 5 Prices @ USGC (CPG)

- EtOH = 235
- UL 87 = 194
- RBOB = 198
Economics – Ethanol Production Costs

- Highly dependent on feedstock cost
- US sugar already heavily subsidized
  Sugar to EtOH easier than starch to EtOH
- Cellulose to ethanol the most difficult,
  technology still evolving
- Corn is best in US
- Brazil burns bagasse in many plants
- Brazil labor costs < US
- Brazil still has best economics

All normalized to US Corn @ $2.50 / per Bushel

Sources: Various Consultants
Economics – Comments on Efficiency

- Industry is growing rapidly, but generally is operating inefficiently
- Some small plants have logistics disadvantages --- far from rail lines; small in scale --- **BUT** local economic impact drove the locations
- Current average plant capacity of 52 MMGPY limits use of unit trains;
- New technologies reducing energy consumption, improving efficiency, developing new co-products, using new feedstocks
  - Seed research to increase corn & ethanol yields
  - Corn fractionation
  - Cold starch hydrolysis
  - Corn oil extraction
  - Lower gas usage --- biomass, fluidized bed reactors, turbines
- Plant in West Texas to use methane from adjacent cattle feed lot and sell co-products as animal feed
Economics - Barriers to Market Entry

- Entry barriers are low - "NIMBY" non-existent due to local benefit --- Rural communities want the jobs generated

- Only 4 firms design / engineer ethanol plants --- same cost pressures as refining industry

- Financing readily available from banks, venture capitalists, hedge funds at favorable rates

- Easier to obtain financing for larger plants --- lenders at this level comfortable with commodity risks

- But Biodiesel is an "easier" process
Pro Forma Economics

- Invest then 1 year to build
- 100% Equity Financing
Pro Forma Economics

Dry Mill Ethanol Economics - IRR Sensitivity

- 10% gas savings = IRR + 1%
- 10 cpg delta EtOH = delta IRR ~3-8%
- Most important --- Corn & EtOH prices

Corn, $ per Bushel

IRR

0% 5% 10% 15% 20% 25% 30% 35%

$2.00 $2.50 $3.00 $3.50 $4.00 $4.50
**Economics – IRR Sensitivity**

<table>
<thead>
<tr>
<th></th>
<th>$2.50</th>
<th>$3.50</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn Price</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Capex 200 MM (% IRR)</strong></td>
<td>24</td>
<td>13</td>
</tr>
<tr>
<td><strong>EtOH @ BTU Parity in 2009</strong></td>
<td>&lt;0</td>
<td>&lt;0</td>
</tr>
<tr>
<td><strong>Base Case - 165 MM Capex (% IRR)</strong></td>
<td>29</td>
<td>16</td>
</tr>
<tr>
<td><strong>EtOH @ BTU Parity in 2009</strong></td>
<td>&lt;0</td>
<td>&lt;0</td>
</tr>
<tr>
<td><strong>Capex 130 MM (% IRR)</strong></td>
<td>37</td>
<td>21</td>
</tr>
<tr>
<td><strong>EtOH @ BTU Parity in 2009</strong></td>
<td>&lt;0</td>
<td>&lt;0</td>
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Financiers already are demanding greater equity stake by plant owners --- 60-65% debt leverage had been the norm
The Future - How Do Biofuels Fit in US system?

• All have a place, but none totally replaces gasoline
  • EtOH and Biobutanol are good octane boosters
  • Biobutanol better than EtOH

• All appear to have GHG advantages over hydrocarbon based fuels

• Some have performance advantages
  • BD zero sulfur, adds lubricity
  • Biobutanol has BTU and shipping advantage over EtOH
  • BD can be made from waste fats and grease
  • Cellulosic EtOH “Changes the rules”

• But some key disadvantages
  • EtOH can’t ship via pipelines
  • BD (Biodiesel) can, BUT how does it impact
  • Until cellulosic or waste grease proven, “food vs. fuel”
  • BD reputation damaged by “garage shop” manufacturers
Back-Up Slides
Brazilian Ethanol (EtOH)

- Made from sugar cane since 1930s
- Low cost global producer - - - But cost varies with sugar prices
- Brazilian Gasoline
  - Hydrous 95% EtOH --- “Ethanol cars” and export
  - Anhydrous EtOH --- “Gasohol” for “flex-fuel” vehicles
  - Conventional refinery gasoline
- 2006 EtOH Production 4.2 BG (273 MBD); ~45 MBD Exported
- Plans to almost double production by 2009
Competing Ethanol Technologies

Corn Processes

• Gas savings to 60% in corn based with Fluidized Bed Reactors or gas turbines
• Location near feed lots reduces methane and animal feed costs
• Seed research underway to improve ethanol yield per bushel of corn
• Proximity of feed and CO2 markets, nat gas price drive corn / EtOH logistics
• Wet mill by-products require additional processing and add costs

Cellulosic Processes

• Available for 25-30 years; never economic, technology unproven on large scale
• *May have* very long term potential to produce “diesel-like” molecules
Economics - Corn vs Ethanol Logistics

Build Near Feedstock or Near Fuel Market?
Ship Ethanol or Ship Corn?

Feedstock cost, 2/3 of total Opex, increases for “destination plants” such as Northeast Biofuels in upstate NY

Concept works when:

- Livestock feed demand is nearby
- Local CO₂ markets exist
- Natural gas prices are reasonable
- Nearby mogas demand is high
Competing Technologies – Dry Milling

Dry Milling

• Grind entire kernel into flour
• Slurry with water & add enzymes
• Convert starch to dextrose (NH3 for pH)
• Heat to reduce bacteria levels
• Cool, add yeast & ferment to EtOH & CO2 over 40 to 50 hours
• Transfer to distillation columns to separate EtOH "stillage"
• EtOH distilled 190 proof (95%)
• Dehydrated to ~200 proof in a molecular sieve system
• Denatured with about 5% natural gasoline

• Stillage centrifuged to separate coarse grain from solubles
• Solubles concentrated to ~30% solids by evaporation --- (Condensed Distillers Solubles (CDS) or "syrup"
• Coarse grain & syrup dried to produce dried distillers grains with solubles (DDGS)
• CO2 captured and sold for soft drink carbonation & dry ice

Source: Renewable Fuels Association
Competing Technologies – Wet Milling

Wet Milling

- Soak grain in dilute sulfurous acid 24 – 48 hrs
- Grind slurry to separate corn germ
- Extract corn oil from germ on-site or sell germ to crushers
- Separate remaining fiber, gluten, starch with centrifugal, screen, hydroclonic separators
- Concentrate steeping liquor & co-dry with fiber portion & sell as corn gluten feed to livestock industry
  - can sell heavy steep water as feed ingredient directly
  - also can use in “Ice Ban”
- Filter and dry gluten (protein) to gluten meal, a valuable poultry feed
- Process starch and any water from mash:
  a) ferment into EtOH (similar to dry milling)
  b) dry, sell as dried / modified corn starch
  c) process into corn syrup

Source: Renewable Fuels Association
Competing Technologies – Cellulosic Biomass

Cellulosic Ethanol

- Variety of options for pretreatment
- Variety of other steps in the process
- Several technologies combine two or all three of the hydrolysis and fermentation steps
- An evolving technology that has yet to be proven commercially
  - Capex = 4 x Dry Milling
  - OPEX = 1.5 times Dry Milling
  - Highest energy cost of all processes
  - But Potentially zero cost feedstock