Growing Competitiveness of Renewable Energy, Beyond the Energy Bill of 2005

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Certified Pest Managers Short Course
November 21, 2005
Topics to be Discussed

• Composition of U.S. Energy Usage
• History and Projections in Usage
  – Transportation (Liquid Fuels)
  – Electrical Generation
• Key features of Energy Bill
  – Ethanol and Biodiesel Production
  – Wind and Other Renewables
• Review USDA Analysis of Energy Bill
• Growing Competitiveness of
  – Renewable Ethanol from Corn
  – Biodiesel from Soybean Oil
  – Biomass for Gasification, Pyrolysis, or Ethanol
  – Wind Energy
• Conclusions for Midwestern Agriculture
Figure 2. Delivered energy consumption by sector, 1970-2025 (quadrillion Btu)
Figure 3. Energy consumption by fuel, 1970-2025 (quadrillion Btu)
Figure 5. Electricity generation by fuel, 1970-2025 (billion kilowatthours)
Figure 5 -- U.S. agriculture has been using less energy since the late 1970s

Electricity

Natural gas

LP gas

Diesel

Gasoline

Fertilizers and pesticides
Bushels of Corn per Pound of Fertilizer

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2005 Energy Bill Features & Projections
Key Features of Energy Bill

- Boosts production of ethanol & biodiesel in several ways
- Corn-based ethanol will dominate.
- Reformulated Gasoline Standards will be removed to allow more flexibility to marketers of gasoline.
- “Renewable Fuel Standard” Credits will be established and traded.
- Cellulosic ethanol is encouraged.
- PTC on Wind is extended through 2007
- Biodiesel Tax Credit 2005 - 2008 (Jobs Bill)
U.S. produced 3.41 and imported 0.17. The total is up from 2.8 in 2003. Domestic production for 2005 should be close to domestic use.

<table>
<thead>
<tr>
<th>Four Market Segments</th>
<th>Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallons</td>
<td>%</td>
</tr>
<tr>
<td>For Ethanol in 2004.</td>
<td></td>
</tr>
<tr>
<td>• Oxy-fuel program</td>
<td>290</td>
</tr>
<tr>
<td>• Reformulated Gasoline</td>
<td>1,950</td>
</tr>
<tr>
<td>• Octane booster &amp;blending</td>
<td>1,050</td>
</tr>
<tr>
<td>• State Mandate (MN)</td>
<td>280</td>
</tr>
<tr>
<td>Total</td>
<td>3,570</td>
</tr>
</tbody>
</table>

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## Annual Production Targets for Renewable Fuels

<table>
<thead>
<tr>
<th>Year</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>4.0 Billion Gal.</td>
</tr>
<tr>
<td>2007</td>
<td>4.7 Billion Gal.</td>
</tr>
<tr>
<td>2008</td>
<td>5.4 Billion Gal.</td>
</tr>
<tr>
<td>2009</td>
<td>6.1 Billion Gal.</td>
</tr>
<tr>
<td>2010</td>
<td>6.8 Billion Gal.</td>
</tr>
<tr>
<td>2011</td>
<td>7.4 Billion Gal.</td>
</tr>
<tr>
<td>2012</td>
<td>7.5 Billion Gal.</td>
</tr>
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</table>
Background and Status: U.S. Ethanol & Biodiesel Production

- Ethanol’s capacity continues to grow rapidly. (Approx. 4 Bill. Gallons in 2005 or 3% of U.S. gasoline supply.)
- Ethanol plants have been quite profitable in recent years, but returns can be volatile.
- Biodiesel is experiencing growth; but it starts from a much lower level. (25 million gallons in 2004)
- Biodiesel can never comprise as high a share of distillate supply due to limited feedstock supplies.
- Dominant feedstock is soybean oil, although recycled oils can be used.
- Ethanol and biodiesel receive substantial subsidies.
U.S. Ethanol Production Capacity with Projection to 2012

With Ethanol Representing 87.5% of RFS

Includes Current Capacity and Plants under Construction

Millions of Gallons

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Do we have enough corn to supply the expanding ethanol industry?

<table>
<thead>
<tr>
<th>Year</th>
<th>Ethanol Prod. (Bil. Gal)</th>
<th>Corn Use For Ethanol (Mil. Bu.)</th>
<th>Corn Crop* (Mil. Bu.)</th>
<th>% Corn Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>03/04</td>
<td>3.4</td>
<td>1,259</td>
<td>10,089</td>
<td>10</td>
</tr>
<tr>
<td>04/05</td>
<td>3.7</td>
<td>1,370</td>
<td>11,741</td>
<td>12</td>
</tr>
<tr>
<td>05/06</td>
<td>4.0</td>
<td>1,482</td>
<td>10,985</td>
<td>13</td>
</tr>
<tr>
<td>06/07</td>
<td>6.0</td>
<td>2,222</td>
<td>10,850</td>
<td>20</td>
</tr>
</tbody>
</table>

- Will need to increase corn acres by shifting land from soybeans or from CRP. Each billion gallons requires about 370 million bushels, or 2.5 to 3 million acres of corn. We may need to shift acres from soybeans and CRP.

* USDA estimates.
USDA Analysis of Energy Bill through 2012

- Additional ethanol will primarily be derived from corn at dry-grind facilities.
- Corn prices will increase 8% ($0.30 per bushel) increase in U.S. by 2012.
- Ample DDGS supplies will reduce prices of SBM 7%.
- Demand to make biodiesel will raise soy oil price 6%.
- Corn acres will rise 3.5%.
- Soybean acres will rise 3%.
- Broiler and turkey production will expand due cheaper SBM.
- Production of all other livestock will decline due to higher corn prices.
- Expect biomass ethanol and biodiesel to be more important after 2012.
Examples of Renewables Competing with Fossil Fuels
Monthly Rack Ethanol & Gasoline Prices (01/02-08/05)
Source: Nebraska Energy and Nebraska Ethanol Board

$0.00 $0.50 $1.00 $1.50 $2.00 $2.50


$ per gallon

Ethanol

Gasoline
Corn and Natural Gas Prices, 1999-2005

Source: U.S Energy Information Administration, and USDA National Agricultural Services
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Ethanol Plant Revenue and Expenses (2005)
Prices of DDGS and Corn per Ton from Jan. 2000 through June 2005
Price per Million BTU (1999-2005)

$/MMBTU

Natural Gas
Corn
## Utilization of DDGS as Fuel

(Morey, Tiffany, Hatfield)


<table>
<thead>
<tr>
<th>Natural Gas Price ($/MM Btu)</th>
<th>DDGS @ $73 per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proc. Heat</td>
<td>Chp</td>
</tr>
<tr>
<td>$5.28</td>
<td>1.7</td>
</tr>
<tr>
<td>$6.33</td>
<td>3.3</td>
</tr>
<tr>
<td>$7.39</td>
<td>4.9</td>
</tr>
<tr>
<td>$8.44</td>
<td>6.5</td>
</tr>
<tr>
<td>$9.50</td>
<td>8.2</td>
</tr>
</tbody>
</table>
Ethanol Plant Responses to NG Prices

- Ethanol Plant replacing NG with DDGS or Syrup
  - Corn Plus (Winnebago)
- Ethanol Plant replacing NG with Waste Wood
  - Central Minnesota Ethanol (Little Falls)
- DDGS are produced at dry-grind ethanol plants in amounts sufficient to provide process heat, electricity in co-generation, and electricity to sell on grid.
- Ethanol Plants switching from DDGS to WDGS
- Ethanol Plants replacing NG with Coal
Projected DDGS Available in U.S. for Feeding or Burning 2004-2012, Assuming Steady Exports
Ethanol Summary

- Ethanol production has been profitable, but it will soon face disruption of traditional markets as oxygenate in mandated markets.
- Usage of ethanol by petroleum marketers is hindered by
  - Technical issues at refineries in removing more volatile fractions
  - Inability to utilize pipelines to transport ethanol
- Ethanol Markets will witness
  - increased use of ethanol as a fuel extender
  - increased use of ethanol as an octane booster
  - the closing of older and smaller ethanol plants
- Ethanol plants are
  - turning to coal and biomass in response to high NG Prices
  - seeking more opportunities to feed WDDG products
  - Investigating fractionation technologies to increase capacity, diversity their portfolio of byproducts, and segregate less valuable fractions for use as fuel.
Biodiesel
Biodiesel: Background

- Smaller Market than Ethanol
- Diesel Usage in the U.S. – approx. 1/3 of Gasoline
- MN Per Capita Usage
  - 500 gal. of Gasoline, 160 gal. of Diesel
- Until recently Biodiesel has been more Costly than Petro-Diesel
- Excellent Fuel w/low Emissions; Usually Blended
- Low Blends Enhance Lubricity in Low-sulfur Diesel Fuel
- U.S. Production Levels of Biodiesel at 30 MM gal. in 2005 vs 450 MM gal. in Europe
- Niche Markets to Reduce Emissions—mines, buses
Production Economics of Biodiesel

• Highly dependent on cost of feedstock, whether vegetable oils such as rapeseed oil, soybean oil, sunflower oil, yellow grease, or animal fats.
• Haas, et al. estimate soy oil is 86% of cost
• Other ingredients used---
  – methanol (made from Natural Gas)
  – Catalysts such as KOH and NaOH
• Crude glycerol is a by-product
Potential Biodiesel Production:

- If all U.S. fat and oil feedstocks were processed for biodiesel 13.3% of U.S. diesel supply could be replaced.--- (Duffield et al.)
- Minnesota could produce 47% of its diesel requirement if all soybeans produced in the state were crushed and the oil used for biodiesel.
### U.S. Feedstocks for Biodiesel

(Eidman)

- **Vegetable Sources**
  - Soy Oil 18,309 MM lb  2,378 MM gal.
  - Corn Oil  2,436 MM lb  316 MM gal.
  - Oth. Crop  1,691 MM lb  271 MM gal.
  - Subtotal  22,436 MM lb.  2,965 MM gal.
U.S. Biodiesel Feedstocks (cont.)

- Recycled and Animal Sources
  - Yellow Grease  2,656 MM lb.  345 MM gal.
  - Lard           1,090 MM lb   142 MM gal.
  - Edible Tallow  1,894 MM lb   246 MM gal.
  - Inedible Tallow 3,696 MM lb  480 MM gal.
  - Subtotal       9,336 MM lb   1,213 MM gal.

- Total Supply   32,173 MM lb  4,178 MM gal.
U.S. Biodiesel Market: How Big? How Fast?

• 30 Million Gal. of B100 sold in U.S. 2004 with support from Bioenergy Credit.
• On Sept. 29, Minnesota Biodiesel Mandate started
• In mid-2006 “lubricity” market kicks-in.
• At the federal level:
  – 1% blend would require 470 MM gal. in 2010
  – 1% 630 MM gal. in 2020
Price of No. 2 Diesel Fuel in Minnesota Excluding Tax, Jan 99- Jul 05
Source: Energy Information Agency
Biodiesel Costs Based on Soybean Oil Costs with Credit for Glycerol

Cost of Soy Oil  ($/pound)

Cost of Biodiesel ($/Gal.)

(Source: Haas, et al., Bioresource Technology, Elsevier)
Conclusions: Biodiesel

- Biodiesel Production in the U.S. has been slow compared to Europe.
- Capacity is apparently in place for considerable production; however, infrastructure to blend may be lacking.
- Biodiesel Tax Credit Should keep biodiesel price nearly equal to petro-diesel through 2008.
- Niche markets will be important, such as school transit buses, and heating oil
- National market will be to serve as lubricity agent in Ultra Low Sulfur Diesel Fuel
- Lacking Biodiesel Tax Credit, yellow grease will be competitive with Soy Oil
- Tallow and Lard may be bid away from uses in feeding, which have been diminishing due to BSE and other animal health issues.
Biomass Feedstocks for Gasification, Pyrolysis or Ethanol Production

Switchgrass  Wheat Straw  Hybrid Poplar  Corn Stalks

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Corn Stover as a Feedstock for Gasification or Pyrolysis*

- Corn Yield of 150 bu. Per Acre
  - 3.15 T/A
- Stover Removed
  - 2.0 T/A
- ISU . Est. per T of Stover 6 lb. Of Phos.
  - 25 lb. Of K
- Value of Nutrients: $6.88 /T.
Combustion Efficiency of Stover  
(Hansen, AURI)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Cost</th>
<th>Efficiency</th>
<th>$/MM BTU</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2 Heating Oil</td>
<td>$2.85/ Gal.</td>
<td>80%</td>
<td>$25.45</td>
</tr>
<tr>
<td>Propane</td>
<td>$1.40/ Gal</td>
<td>80%</td>
<td>$19.16</td>
</tr>
<tr>
<td>Corn Shelled</td>
<td>$1.85/ Bu.</td>
<td>80%</td>
<td>$5.96</td>
</tr>
<tr>
<td>Corn Stover</td>
<td>$32-$48/T.</td>
<td>40-60%</td>
<td>$5.97</td>
</tr>
<tr>
<td>Corn Cobs</td>
<td>$62/T.</td>
<td>70%</td>
<td>$6.01</td>
</tr>
</tbody>
</table>
Review of Ligno-Cellulosic Ethanol

- Cellulose and Hemicellulose are made from carbohydrates.
- Cell. & Hemicell are cross-linked with numerous hydrogen bonds. Lignin adds form to these structural parts of plants.
- Lignin, with energy density nearly equal to coal, would be used to produce process heat, electricity with electricity to sell on elect. grid.
- Acid pre-treatments are needed to prepare cellulosic feedstocks for enzymatic processing.
- Bacteria were assumed to be used for fermentation.
- Studies by Aden (U.S. DOE), Wooley (U.S. DOE) and McAloon (USDA) identify parameters of this process.
- Enzyme activity and cost improvements have been reported on U.S. DOE research conducted by Novozymes and Genencor.
- Iogen (partnered w/Shell) has produced thousands of gallons of ethanol fr wheat straw; building test plant to produce 1MM gallons per year.
Energy Balance by Feedstock & Technology  (Source: Christoph Berg, F.O. Licht)

- Rapeseed Biodiesel: 3.50
- Wheat--Ethanol: 1.30
- Corn (Dry-Gr) Ethanol (Shapouri et al): 1.77
- Sugar Beet--Ethanol: 1.85
- Ligno-cell.-- Ethanol: 6.00
- Sugar Cane--Ethanol: 8.00
Factors for Ligno-Cellulosic Ethanol Production Cost

- Capital Costs are **Triple** the Costs of Dry-Mills per Unit of Capacity. (Perhaps difficult to raise capital, >sensitivity to interest rates.)

- Cost of Feedstocks: $30 to $50 per Ton < corn ($80/ T. @ $2.20/ bu.)

- Conversion Rates with Cellulosic Crops
  - Near Term: 69.7 gallons/Ton  (5-7 days saccharification & fermentation)
  - Future Term: 89.7 gallons/Ton  (3-3.5 days saccharification & fermentation)
  - Theoretical: 112.7 gallons/Ton

**Dry-Grind (Corn):** 114 gallons/Ton + 643 lb. DDGS

- Cellulosic Enzyme Costs Range from $.40--$.25--$.10 per gal. denatured ethanol produced.

- **Processing time to achieve conversion rates has not been disclosed.**
Ethanol Cost Per Denatured Gallon Derived from $50/Ton Corn Stover

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Future</td>
<td>89.7 Gal./Ton</td>
<td>$0.10</td>
<td>$1.25</td>
</tr>
<tr>
<td></td>
<td>$0.25</td>
<td></td>
<td>$1.40</td>
</tr>
<tr>
<td>Base</td>
<td>67.8 Gal./Ton</td>
<td>$0.10</td>
<td>$1.65</td>
</tr>
<tr>
<td></td>
<td>$0.25</td>
<td></td>
<td>$1.79</td>
</tr>
</tbody>
</table>
What Conditions of Dry-Mill Plants Would Equal These Denatured Ethanol Costs?

<table>
<thead>
<tr>
<th>Ethanol Cost</th>
<th>Corn Cost</th>
<th>NG Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Future Conversion@ 89.7 gal./T.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1.25</td>
<td>$2.35</td>
<td>$7.00 DkTh</td>
</tr>
<tr>
<td>$1.40</td>
<td>$2.98</td>
<td>$7.00 DkTh</td>
</tr>
<tr>
<td><strong>Base Conversion@ 67.8 gal./T.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$1.65</td>
<td>$4.02</td>
<td>$7.00 DkTh</td>
</tr>
<tr>
<td>$1.79</td>
<td>$4.62</td>
<td>$7.00 DkTh</td>
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Dry-Grind Production Cost of Denatured Ethanol for Various Corn Prices: Nat. Gas @ $7.00 /DekaTh, DDGS @ Corn Price/Ton and 12% ROR

<table>
<thead>
<tr>
<th>Price of Corn per Bushel</th>
<th>Optimistic Ligno-Cell. Scenario</th>
<th>Pessimistic Ligno-Cell. Scenario</th>
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</thead>
<tbody>
<tr>
<td>$1.80</td>
<td>$1.80</td>
<td>$1.80</td>
</tr>
<tr>
<td>$2.35</td>
<td>$2.35</td>
<td>$2.35</td>
</tr>
<tr>
<td>$2.98</td>
<td>$2.98</td>
<td>$2.98</td>
</tr>
<tr>
<td>$4.02</td>
<td>$4.02</td>
<td>$4.02</td>
</tr>
<tr>
<td>$4.62</td>
<td>$4.62</td>
<td>$4.62</td>
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<tr>
<td>$5.00</td>
<td>$5.00</td>
<td>$5.00</td>
</tr>
</tbody>
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Project Economics: Wind-Biodiesel Co-Generation
Background on Wind Power

- Cost-Competitive
- Clean
- Growing Rapidly
- Requires Fed. & State Incentives
- Still a Small Share
Figure 1: Levelized Electricity Costs for New U.S. Plants in 2015

Source: Energy Information Agency, Annual Energy Outlook 2005,
Market Trends - Electricity Demand and Supply
### Emissions per KWH of Electricity Generated in U.S., in Pounds

*Source: EIA Annual Energy Review 1998*

<table>
<thead>
<tr>
<th>Fuel</th>
<th>CO2</th>
<th>SO2</th>
<th>NOx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>2.13</td>
<td>0.013400</td>
<td>0.0076</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1.03</td>
<td>0.000007</td>
<td>0.0018</td>
</tr>
<tr>
<td>Oil</td>
<td>1.56</td>
<td>0.011200</td>
<td>0.0021</td>
</tr>
<tr>
<td>U.S. Average Mix</td>
<td>1.52</td>
<td>0.008000</td>
<td>0.0049</td>
</tr>
<tr>
<td>Wind</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
U.S. Installed Wind Generating Capacity in MegaWatts

Source: American Wind Energy Association
Sources of U.S. Electrical Power in 2004

Source: Energy Information Agency

- Coal, 51%
- Natural Gas, 18%
- Nuclear, 20%
- Petroleum, 2%
- Hydro-power, 7%
- Other Renewables, 2%
- Wind, 0.27%
Conclusions

• Interesting Times for Energy Prices and Supplies
• Emerging Technologies are Spurred by High Cost Fossil Energy
• Lower Emissions and Lower GHG of renewables will become important in context of international climate change treaties
If my projections are wrong, check with my Complaint Department next year at this meeting.
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- Staff Paper:

  “Agriculture as Producer and Consumer of Energy,” (Farm Foundation) book chapter by Vernon Eidman