Looking at the Economics of the Next Generation of Biofuels

Chad Hart
Center for Agricultural and Rural Development
Iowa State University
E-mail: chart@iastate.edu

May 27, 2008

“Breeding Lignocellulosic Crops for the Bioeconomy”
Plant Breeding Lecture Series
Iowa State University
Ames, Iowa
Crude Oil Futures Prices

Source: NYMEX, May 23, 2008
## Liquid Fuel Use

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Million Barrels Oil Equivalent per Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>20.7</td>
<td>103</td>
<td>109</td>
<td>115</td>
<td>121</td>
<td>129</td>
</tr>
<tr>
<td>Canada</td>
<td>2.3</td>
<td>100</td>
<td>100</td>
<td>104</td>
<td>104</td>
<td>104</td>
</tr>
<tr>
<td>Mexico</td>
<td>2.0</td>
<td>110</td>
<td>115</td>
<td>130</td>
<td>135</td>
<td>145</td>
</tr>
<tr>
<td>Europe</td>
<td>15.6</td>
<td>99</td>
<td>99</td>
<td>100</td>
<td>101</td>
<td>101</td>
</tr>
<tr>
<td>Japan</td>
<td>5.4</td>
<td>96</td>
<td>96</td>
<td>96</td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td>China</td>
<td>6.4</td>
<td>147</td>
<td>164</td>
<td>186</td>
<td>213</td>
<td>245</td>
</tr>
<tr>
<td>India</td>
<td>2.5</td>
<td>108</td>
<td>128</td>
<td>144</td>
<td>160</td>
<td>176</td>
</tr>
<tr>
<td>Africa</td>
<td>2.8</td>
<td>118</td>
<td>139</td>
<td>154</td>
<td>164</td>
<td>175</td>
</tr>
<tr>
<td>Central and South America</td>
<td>5.4</td>
<td>120</td>
<td>137</td>
<td>152</td>
<td>167</td>
<td>180</td>
</tr>
<tr>
<td>World</td>
<td>82.5</td>
<td>110</td>
<td>118</td>
<td>126</td>
<td>134</td>
<td>143</td>
</tr>
</tbody>
</table>

**Source:** EIA, International Energy Outlook 2007
Countries Pursuing Biofuels

- US
- Brazil
- Argentina
- Colombia
- Paraguay
- Canada
- Uruguay
- Mexico
- Thailand
- New Zealand
- South Africa
- South Korea
- Philippines
- Indonesia
- Pakistan
- China
- India
- Malaysia
- Australia
- Japan
- EU
- Russia
- Not a complete list
Currently Available Biomass

Biomass Resources Available in the United States

Source: NREL, 2005
Spectrum of Biofuels

- Grain/Sugar Ethanol
- Biodiesel
- Green Gasoline/Diesel
- Cellulosic Ethanol
- Butanol
- Pyrolysis liquids
- Syngas liquids

Most Mature

Least Mature

Source: NREL, 2006
Biofuel Challenges

- Production costs
  - Conversion, ag. production, etc.
- Infrastructure barriers
  - Developing supply chain for biomass
  - Continued development of biofuel distribution system
- Growth in biofuel-compatible vehicles
Biofuel Challenges

- Investment risks
  - Higher capital costs, emerging technology
- Biomass production shifts
  - Inducing farmers to produce new crops
- Consumer understanding
  - About the fuels
  - About the tradeoffs
Progress on Cellulosic Costs

State of Technology Estimates

Minimum Ethanol Selling Price ($ per gal)

- Enzyme
- Feedstock
- Conversion

Costs in 2002 Dollars

2000
- $53 per ton
- Yield 65 gal/ton

2005
- $35 per ton
- Yield 90 gal/ton

DOE Cost Target

Source: NREL, 2007
### Comparing Costs, 150 Million Gallons Gasoline Equivalent, 2005 $

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Capital Costs ($ Million)</th>
<th>Operating Costs ($/Gallon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain</td>
<td>111</td>
<td>1.22</td>
</tr>
<tr>
<td>Cellulosic</td>
<td>756</td>
<td>1.76</td>
</tr>
</tbody>
</table>

### Production and Infrastructure Costs

#### Costs for Agricultural Straws and Switchgrass

<table>
<thead>
<tr>
<th></th>
<th>2007 Cost ($ per dry ton)</th>
<th>2017 Projected Cost ($ per dry ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>13.10</td>
<td>26.20</td>
</tr>
<tr>
<td>Harvest &amp; Collection</td>
<td>18.40</td>
<td>10.60</td>
</tr>
<tr>
<td>Storage &amp; Queuing</td>
<td>6.10</td>
<td>3.70</td>
</tr>
<tr>
<td>Preprocessing</td>
<td>7.80</td>
<td>6.20</td>
</tr>
<tr>
<td>Transportation &amp; Handling</td>
<td>14.70</td>
<td>12.30</td>
</tr>
</tbody>
</table>

**Source:** DOE, Biomass Multi-Year Program Plan, March 2008
### Production and Infrastructure Costs

<table>
<thead>
<tr>
<th>Costs for Agricultural Stovers</th>
<th>2007 Cost ($ per dry ton)</th>
<th>2017 Projected Cost ($ per dry ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>13.10</td>
<td>26.20</td>
</tr>
<tr>
<td>Harvest &amp; Collection</td>
<td>29.50</td>
<td>10.60</td>
</tr>
<tr>
<td>Storage &amp; Queuing</td>
<td>22.20</td>
<td>8.60</td>
</tr>
<tr>
<td>Preprocessing</td>
<td>16.40</td>
<td>7.80</td>
</tr>
<tr>
<td>Transportation &amp; Handling</td>
<td>20.10</td>
<td>14.70</td>
</tr>
</tbody>
</table>

Source: DOE, Biomass Multi-Year Program Plan, March 2008
## Conversion Costs

### Costs for Corn Stover, 2007 $

<table>
<thead>
<tr>
<th></th>
<th>2005 Cost ($ per gallon)</th>
<th>2012 Projected Cost ($ per gallon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretreatment</td>
<td>0.44</td>
<td>0.25</td>
</tr>
<tr>
<td>Enzymes</td>
<td>0.32</td>
<td>0.10</td>
</tr>
<tr>
<td>Fermentation</td>
<td>0.31</td>
<td>0.10</td>
</tr>
<tr>
<td>Distillation &amp; Solids</td>
<td>0.18</td>
<td>0.15</td>
</tr>
<tr>
<td>Recovery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethanol Yield</td>
<td>65.3</td>
<td>89.8</td>
</tr>
</tbody>
</table>

### Source: DOE, Biomass Multi-Year Program Plan, March 2008
## Conversion Costs

### Costs for Hybrid Poplar, 2007 $

<table>
<thead>
<tr>
<th></th>
<th>2006 Cost</th>
<th>2012 Projected Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>($ per gallon)</td>
<td>($ per gallon)</td>
</tr>
<tr>
<td>Feed Handling &amp; Drying</td>
<td>0.18</td>
<td>0.16</td>
</tr>
<tr>
<td>Gasification</td>
<td>0.14</td>
<td>0.13</td>
</tr>
<tr>
<td>Synthesis Gas Clean-up</td>
<td>0.69</td>
<td>0.43</td>
</tr>
<tr>
<td>Fuel Synthesis</td>
<td>0.08</td>
<td>-0.03</td>
</tr>
<tr>
<td>Product Purification</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Ethanol Yield</td>
<td>63.2</td>
<td>69.8</td>
</tr>
</tbody>
</table>

Source: DOE, Biomass Multi-Year Program Plan, March 2008
Switchgrass in the Plains

- Found ethanol yields per acre comparable to corn grain ethanol

- But indicated that switchgrass would likely be targeted to marginal land where row crop production is less profitable

## Competing for Acreage

<table>
<thead>
<tr>
<th>Crop</th>
<th>Net Return ($ per acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>115 – 135</td>
</tr>
<tr>
<td>Rice</td>
<td>230 – 370</td>
</tr>
<tr>
<td>Corn</td>
<td>330 – 400</td>
</tr>
<tr>
<td>Sorghum</td>
<td>85 – 105</td>
</tr>
<tr>
<td>Soybeans</td>
<td>305 – 345</td>
</tr>
<tr>
<td>Cotton</td>
<td>150 – 200</td>
</tr>
</tbody>
</table>

Source: FAPRI, 2008
Renewable Fuels Standard

Billion gallons

- Conventional Ethanol
- Biodiesel
- Cellulosic Biofuels
- Additional Advanced Biofuels

50% GHG Emission Reduction
60% GHG Emission Reduction

2009 2012 2015 2018 2021
Cellulosic Biofuel Waiver Provisions

- EPA (in consultation with DOE and USDA) can reduce the cellulosic biofuel mandated volume

- Waiver trigger based on EIA projections

- EPA will also sell cellulosic biofuel credits
  - Price set at Max($0.25 per gallon, $3.00 – Average wholesale gasoline price per gallon)
Components of 2007 Energy Act

- Up to $500 million per year in grants for the production of advanced biofuels (with at least an 80% reduction in GHG emissions relative to current fuels)

- Up to $25 million per year in grants for R&D for biofuel production in states with low rates of biofuel production
Energy in the Farm Bill

- Grants for the development and construction of advanced biofuel biorefineries, up to 30% of the cost of the project.

- Loans for the same, up to $250 million or 80% of the cost per project.
Bioenergy Program for Advanced Biofuels

- Payments to support advanced biofuel production

- Payment structure to be determined by USDA

Bioenergy Program for Advanced Biofuels

- Discretionary funding: $25 million each year

- Not more than 5% of the funds can be directed to biorefineries with production capacities above 150 million gallons per year
3 key areas of direction
- Feedstock development
- Biofuels and biobased products development
- Biofuels development analysis

Funding
- Mandatory: $20-40 million for 2009-2012
- Discretionary: $35 million each year
Biomass Crop Assistance Program

- To support production of crops for bioenergy and assist with collection, harvest, storage, and transportation of biomass to conversion facilities

- Excluded materials
  - Farm program crops, animal byproducts, food waste, yard waste, algae
Biomass Crop Assistance Program

- Requires producers and conversion facilities to submit proposal establishing a project area.

- Establishes contracts between USDA, producers, and facilities to promote project.

- Sets up establishment payments for perennial crops and annual payment to biomass producers.
Biomass Crop Assistance Program

- Payments are also authorized for biomass collection, harvest, storage, and transportation

- Matching payments
  - $1 for each $1 per ton paid by conversion facility, up to $45 per ton, for 2 years
Other Energy Provisions in the Farm Bill

- Cellulosic biofuel producer tax credit: $1.01 per gallon
  - Restricted to domestic production

- Waives limits on small ethanol producer credit for cellulosic ($0.10 per gallon)
Thank you for your time.

Any questions?