Biomass: Producer Choices, Production Costs and Potential

Francis Epplin
Department of Agricultural Economics
Oklahoma State University

Transition to a Bioeconomy:
The Role of Extension in Energy
June 30-July 1, 2009
Little Rock
Renewable Fuel Standards – RFS 2

36 billion gallons of biofuel by 2022
15 B gal conventional (“Corn Ethanol”)

21 B gal of 2nd generation biofuel
16 B gal of cellulosic (primarily cellulosic ethanol)
4 B gal of advanced biofuel
1 B gal of biomass based diesel
RFS – 2
US EPA estimates of feedstock sources to meet 16 B gal mandate (2022)

- 9.0 B - crop residues
  - 7.8 B - corn stover

- 3.9 B - forestry biomass

- 2.1 B - urban waste

- 0.9 B - switchgrass or other dedicated energy crops
US EPA Projections (Goals) For 2022 (In 2006 Dollars)

- Gasoline @ $2.05 / gal
  Ethanol has 2/3 energy content of Gasoline

- Breakeven Ethanol Price @ $1.35 / gal

- US EPA estimates cellulosic ethanol can be produced for $1.31 / gal
US EPA Projections (Goals) For 2022 (In 2006 Dollars)

Assumptions

• A flow of feedstock can be delivered throughout the year for $73 / dry ton
• Biomass can be converted at a rate of 94 gal / ton
• Cellulosic Ethanol Goal - $1.31 / gal
  – $0.78 for feedstock
  – $0.53 for conversion

• Breakeven Ethanol Price with $2.05 gasoline is $1.35 / gal
## DOE NREL 2012 Goal vs. EPA 2022 Goals

<table>
<thead>
<tr>
<th>DOE NREL (2012 goals)</th>
<th>EPA (2022 goals)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivered feedstock cost of $35/dry ton</td>
<td>Delivered feedstock cost of $73/dry ton</td>
</tr>
<tr>
<td>90 gal/t</td>
<td>94 gal/t</td>
</tr>
<tr>
<td>$0.39/gal – feedstock</td>
<td>$0.78/gal – feedstock</td>
</tr>
<tr>
<td>$0.68/gal – conversion</td>
<td>$0.53/gal – conversion</td>
</tr>
<tr>
<td>Cellulosic Ethanol for $1.07/gal</td>
<td>Cellulosic Ethanol for $1.31/gal</td>
</tr>
</tbody>
</table>

Source: Pacheco 2006

Source: US EPA 2009
The Role of Extension in Energy

Biomass: Producer Choices, Production Costs and Potential
U.S. Energy Market

- **Total 2007 U.S. Energy Consumption**: 101.6 quadrillion Btu
- **Net 2007 U.S. Energy Imports**: 29.2 quadrillion Btu
- **Ethanol from 2.4 billion bu of Corn (U.S. 2007)**: 0.49 quadrillion Btu
- **Potential Ethanol from Total 2007 U.S. Corn Production (13.1 billion bu)**: 2.68 quadrillion Btu
- **Second Generation Biofuel from 21 Billion Gallon Mandate**: 1.60 quadrillion Btu

% of Net 2007 Imports:
- **1.7%**
- **9.2%**
- **5.5%**
US Gasoline and Ethanol Use

![Graph showing US Gasoline and Ethanol Use from 1975 to 2010. Gasoline usage has increased steadily from around 100,000 million gallons in 1975 to over 150,000 million gallons by 2010. Ethanol usage has remained relatively flat, starting at a few million gallons in 1975 and ending at around 5 million gallons by 2010.]
Potential Energy from EISA Mandate for 2022 Relative to 2007 Use
Biomass: Producer Choices, Production Costs and Potential
RFS – 2
US EPA estimates of feedstock sources to meet 16 B gal of cellulosic 2022 mandates

- 9 B - crop residues
  - 7.8 B - corn stover

- 3.9 B - forestry biomass

- 2.1 B - urban waste

- 0.9 B - switchgrass or other dedicated energy crops
Corn Stover
# Corn Stover Cost Estimates

<table>
<thead>
<tr>
<th>Source</th>
<th>Year</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>English et al.</td>
<td>1981</td>
<td>IA</td>
</tr>
<tr>
<td>Gallagher et al.</td>
<td>2003</td>
<td>IA</td>
</tr>
<tr>
<td>Gallagher et al.</td>
<td>2003</td>
<td>KS</td>
</tr>
<tr>
<td>Graham et al.</td>
<td>2007</td>
<td>U.S.</td>
</tr>
<tr>
<td>Glassner et al.</td>
<td>1998</td>
<td>IA</td>
</tr>
<tr>
<td>Khanna</td>
<td>2008</td>
<td>IL</td>
</tr>
<tr>
<td>Petrolia</td>
<td>2008</td>
<td>MN</td>
</tr>
<tr>
<td>US EPA</td>
<td>2009</td>
<td>IN</td>
</tr>
</tbody>
</table>
## Estimates of Corn Stover Cost

<table>
<thead>
<tr>
<th>Source</th>
<th>Location</th>
<th>Harvest ($/ton)</th>
<th>Fertility Replacement ($/t)</th>
<th>Payment to Land Owner/Farmer ($/t)</th>
<th>Harvestable Yield (t/acre)</th>
<th>Farm Gate Cost ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallagher et al.</td>
<td>KS</td>
<td>$6</td>
<td>$6</td>
<td>n.a.</td>
<td>3.33</td>
<td>$12</td>
</tr>
<tr>
<td>Graham et al.</td>
<td>U.S.</td>
<td>$18 - $33</td>
<td>$7</td>
<td>n.a.</td>
<td>1.4 – 2.3</td>
<td>$25 - $40</td>
</tr>
<tr>
<td>Glassner et al.</td>
<td>IA</td>
<td>$15</td>
<td>n.a.</td>
<td>$3 - $15</td>
<td>1.5 - 3.0</td>
<td>$18 - $30</td>
</tr>
<tr>
<td>Khanna</td>
<td>IL</td>
<td>$35</td>
<td>$8</td>
<td>$24</td>
<td>1.85</td>
<td>$67</td>
</tr>
<tr>
<td>Petrolia</td>
<td>MN</td>
<td>n.a.</td>
<td>$4</td>
<td>n.a.</td>
<td>n.a.</td>
<td>$40</td>
</tr>
<tr>
<td>US EPA</td>
<td>IN</td>
<td>$24</td>
<td>$12</td>
<td>$10</td>
<td>2.00</td>
<td>$43 - $46</td>
</tr>
</tbody>
</table>

Range: $12 - $67 / ton
Switchgrass
# Switchgrass Cost Estimates

<table>
<thead>
<tr>
<th>Source</th>
<th>Year</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duffy</td>
<td>2007</td>
<td>IA</td>
</tr>
<tr>
<td>Epplin</td>
<td>1996</td>
<td>OK</td>
</tr>
<tr>
<td>Epplin et al.</td>
<td>2007</td>
<td>OK</td>
</tr>
<tr>
<td>Garland</td>
<td>2008</td>
<td>TN</td>
</tr>
<tr>
<td>Khanna</td>
<td>2008</td>
<td>IL</td>
</tr>
<tr>
<td>Khanna et al.</td>
<td>2008</td>
<td>IL</td>
</tr>
<tr>
<td>Perrin et al.</td>
<td>2008</td>
<td>ND, SD, NB</td>
</tr>
<tr>
<td>Vadas et al.</td>
<td>2008</td>
<td>WI</td>
</tr>
<tr>
<td>USEPA</td>
<td>2009</td>
<td></td>
</tr>
</tbody>
</table>
## Switchgrass Cost Estimates

<table>
<thead>
<tr>
<th>Source</th>
<th>Location</th>
<th>Nitrogen (lb/a)</th>
<th>Land Charge ($/ac)</th>
<th>Mature Yield (tons/acre)</th>
<th>Farm Gate Cost ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duffy</td>
<td>IA</td>
<td>100</td>
<td>$80</td>
<td>4</td>
<td>$82</td>
</tr>
<tr>
<td>Epplin et al.</td>
<td>OK</td>
<td>80</td>
<td>$60</td>
<td>3.75-6.50</td>
<td>$37-$ 53</td>
</tr>
<tr>
<td>Garland</td>
<td>TN</td>
<td>60</td>
<td>n.a.</td>
<td>6.45</td>
<td>$ 62 + Land</td>
</tr>
<tr>
<td>Khanna</td>
<td>IL</td>
<td>n.a.</td>
<td>$77</td>
<td>2.4</td>
<td>$113</td>
</tr>
<tr>
<td>Khanna et al.</td>
<td>IL</td>
<td>100</td>
<td>$78</td>
<td>2.58</td>
<td>$82</td>
</tr>
<tr>
<td>Perrin et al.</td>
<td>ND, SD, NB</td>
<td>67</td>
<td>$60</td>
<td>2.23</td>
<td>$54</td>
</tr>
<tr>
<td>Vadas et al.</td>
<td>WI</td>
<td>125</td>
<td>$80</td>
<td>4.84</td>
<td>$53</td>
</tr>
<tr>
<td>USEPA</td>
<td>n.a.</td>
<td>$62</td>
<td>6.17</td>
<td></td>
<td>$44</td>
</tr>
</tbody>
</table>

**Range:** $37 - $113 / ton
Corn Stover Versus Switchgrass (Farm Gate Cost)

• Corn Stover
  – Range: $12 - $67 / ton
  – US EPA estimate by 2022 $43-$46

• Switchgrass
  – Range: $37 - $113 / ton
  – US EPA estimate by 2022 $44
US EPA Estimates (for 2022) of Average Cost for Flow of Feedstock Throughout the Year
2006 Dollars

• Corn Stover
  – Farm Gate $43-$46
  – Expected Average Total Cost to Biorefinery $89

• Switchgrass
  – Farm Gate $44
  – Expected Average Total Cost to Biorefinery $73
Corn Stover Versus Switchgrass

- Expected Greater Average Transportation Cost for Stover
  - Expect Lower Removable Yield per Acre
  - Bales Expected to be Less Dense

- Expected Greater Average Storage Cost for Stover
  - Narrow Harvest Window
  - More Land Required
  - More Valuable Land
Challenges

• Cost efficiency suggests
  – Year-round operation of the biorefinery
  – Year-round delivery of feedstock

• Optimal size is unknown but 50+ million gallons per year is common for corn ethanol plants

• Anticipate that a cellulosic biorefinery would require 2,000 dry tons per day
Quantity of Feedstock Required for a 2,000 tons per day Biorefinery

- 700,000 tons of biomass per year
- 350 days of operation per year
- 17 dry tons per truck
- 118 trucks per day
- 24 hours per day
- 4.9 trucks per hour
Optimal Biorefinery Size

Costs (e.g. $/gallon) vs. Biorefinery Size (e.g. tons/day)
Feedstock Transportation Cost

Feedstock Transportation Cost (e.g. $/ton)

Biorefinery Size (e.g. tons/year)
Trouble with Stubble

• collection, storage, and transportation of a continuous flow of corn stover is a “…logistical nightmare…”. (Schechinger 2000)

• In the U.S. Corn Belt, stover harvest may be complicated by
  – Rain
  – Mud
  – Snow
  – Fire
  – Stalk moisture retention
  – Narrow harvest window

Corn Stover Harvest Window

- 40 days - IN (Nielsen 1995)
- 21 days – MN (Petrolia 2008)
- 50 days – IN (US EPA 2009)
- Abengoa Bioenergy concluded that in 1 of 7 years corn stover harvest is likely to be limited by weather in Eastern Midwest (Robb 2007)
Dual (Grain & Stover) Harvest Systems

• Expensive

• Grain May be Ready for Harvest but Moisture Content of Stover May be Too High for Safe Storage

• May delay harvest of grain
  – Decrease in Expected Grain Yield
  – Potential Decrease in Grain Quality
    • Potential Decrease in Net Price
Trouble with Stubble

"Our main concern is $4 / bu corn (worth $750 to $800 an acre)," Johnson (a corn producer) said. "$30 / acre for biomass is a minor concern for our operation."

Source:  Bill Hord, 27 March 2007, Omaha World-Herald
Will Switchgrass Work?

Hypotheses

• Not on land suitable for economical production of continuous corn and/or corn-soybeans in rotation

• Perhaps on marginal cropland and cropland pasture (remains to be seen if pasture can be bid from livestock and converted to perennial grasses)
# Grain versus Cellulosic Biomass

<table>
<thead>
<tr>
<th><strong>Corn</strong></th>
<th><strong>Switchgrass</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>– Annual crop</td>
<td>– Perennial</td>
</tr>
<tr>
<td>– Spot markets</td>
<td>– Zero spot markets</td>
</tr>
<tr>
<td>– Infrastructure exists</td>
<td>– Zero Infrastructure</td>
</tr>
<tr>
<td>– Planting, harvesting, transportation, and storage systems</td>
<td>– Limited harvesting, transportation, and storage systems</td>
</tr>
<tr>
<td>– Many alternative uses</td>
<td>– Few alternative uses for mature switchgrass</td>
</tr>
<tr>
<td>– Risk management tools (futures markets) in existence</td>
<td>– No futures markets</td>
</tr>
<tr>
<td>– Farming activities</td>
<td>– After established, not much “farming”</td>
</tr>
</tbody>
</table>
“…The rationale for developing lignocellulosic crops for energy is that …poorer quality land can be used for these crops, thereby avoiding competition with food production on better quality land…. ” (McLaughlin et al. 1999, p. 293).

Feedstock Acres

- US EPA estimates that by 2022 1.6 million acres of Switchgrass
  - 0.06 NH
  - 0.17 WV
  - 1.34 OK

- In 2007 US farmers planted
  - 94 million acres of corn
  - 64 million acres of soybeans
  - 60 million acres of wheat
  - 11 million acres of cotton
Potential Markets for Extension Education

• Biorefineries

• Farmers
  – Access to collection and acquisition of corn stover is likely to be controlled by corn farmers rather than land owners

• Land Owners
  – Use of land to establish switchgrass will require interaction with land owners (perhaps similar to CRP)
  – Biorefinery will compete with farmers for land
Issues

• Jed Clampett experience (windfall gain) is not likely

• Biorefineries will seek least-cost feedstock flow

• Potential Danger for Land Owners
  – Contract voided due to bankruptcy

  – After perennial is established, biorefinery could exercise monopsony power
Abengoa Bioenergy
Hugoton, KS Facility
(planned 10-yr contracts)

- Propose to contract for acres rather than for a specific crop.

- Farmers/landowners are free to plant wheat, grain sorghum, or corn.

- Contracts grant the option to either purchase or to refuse to purchase crop residue available after grain harvest on contracted acres.

- CRP land (subject to USDA restrictions) may be contracted
Abengoa
(planned 10-yr contracts)

$1 / ac paid only in first year - commitment fee
$0.50 / ac / yr as a reservation payment

1. $15 / dry ton
2. $7 plus nutrient replacement cost
3. $10 plus revenue share
   (revenue share = 2.5 * Chicago Board of Trade EtOH futures (capped at $10 / ton))
4. $2 plus revenue sharing plus nutrient replacement

Abengoa will be responsible for harvest, transport, and storage
Potential Role for Government Relative to Establishment of Perennial Crops

- Guarantee or insure payment over the expected life of the crop

- Could use existing CRP infrastructure to facilitate contracting

- CRP was established in 1985
  - By July of 1987 more than 22 million acres were enrolled

- Insurance
Risk?
Challenges to Cellulosic Ethanol

• Economically viable conversion system

• Profitable business model

• Energy is a commodity
  – The least-cost source will be used first
  – In the absence of policy incentives (subsidies, carbon taxes, mandates) extremely difficult to compete with fossil fuels on cost
Acknowledgements

- Oklahoma Agricultural Experiment Station
- USDA/CSREES
- USDA/IFAFS
- USDA/NNF
- Oklahoma Bioenergy Center
- Sun Grant Initiative
- Farm Foundation