Biomass Vision and Roadmap Update

Current status of process

What is the Vision Statement?

- *The Vision for Bioenergy and Biobased Products in the United States was created in 2002*
- *It established far-reaching goals to increase the role of biobased energy and products in our nation’s economy.*
- *It represented the collective vision of the Biomass Research and Development Technical Advisory Committee established by the Biomass R&D Act of 2000.*
Vision Timeline

• Workshop: 11/05
  – 22 experts from industry, government, academia
  – Held at Argonne National Lab
  – Round table discussion to update goals & major challenges
• Peer Review: 1/06
  – 25 experts – 19 responses
  – Electronic submission of comments/edits
• Board Review: 4/06
  – EPA, DOE, USDA, NSI, DOI, DOT, OSTP, OFEE
• Final Vision: 6/06

Post Vision Workshop Agenda

• Obtained Technical Advisory Committee input on Vision Executive Summary.
• Follow-up analysis and peer review carried out to ensure targets were valid in relation to available feedstocks, conversion technologies, etc.
• Developed draft Vision by December 31, 2005.
• Final Vision will be submitted by April 2006.
• The updated *Vision* does not change the original 2010 goals but recognizes that in some cases the U.S. is not on track to meet them.

• The *Vision* makes minor changes to its 2020 and 2030 goals and establishes 2015 goals which describe the types of activities that must occur to reach that goal and move down the path to the aggressive targets for 2020 and 2030.

### Original Vision Goals

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BioPower</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass share of electricity &amp; heat demand in utilities and industry</td>
<td>3% (2.7 quads)</td>
<td>4% (3.3 quads)</td>
<td>5% (4.0 quads)</td>
<td>5% (5.0 quads)</td>
</tr>
<tr>
<td><strong>BioFuels</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biomass share of demand for transportation fuels.</td>
<td>0.5% (0.15 quads)</td>
<td>4% (1.3 quads)</td>
<td>10% (4.0 quads)</td>
<td>20% (9.5 quads)</td>
</tr>
<tr>
<td><strong>BioProducts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share of target chemicals that are biobased.</td>
<td>5%</td>
<td>12%</td>
<td>18%</td>
<td>25%</td>
</tr>
</tbody>
</table>
Updated Vision Goals

<table>
<thead>
<tr>
<th>Units</th>
<th>2000</th>
<th>2004</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biopower</td>
<td>Market share (%)</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5.5</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Consumption (Quadrillion Btu)</td>
<td>2.2</td>
<td>2.1</td>
<td>3.1</td>
<td>3.2</td>
<td>3.4</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Market share (%)</td>
<td>0.7</td>
<td>1.2</td>
<td>4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Consumption (million gasoline-equivalent gallons)</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>Bioproducts</td>
<td>Production (billion lbs)</td>
<td>12.4</td>
<td>17.6</td>
<td>23.7</td>
<td>26.4</td>
<td>35.6</td>
</tr>
</tbody>
</table>

What is the Roadmap?

- The Biomass R&D Act of 2000 called for the USDA and DOE to jointly carry out a biomass research and development initiative in the areas of biofuels and bioproducts.
- It also established the Biomass R&D Technical Advisory Committee to advise on the technical program.
Roadmap Update Process

- Roadmaps will be planned by Regional Chairs with BCS/DOE support
- Roadmaps will incorporate regional experts pertaining to the Roadmap categories: Feedstocks, Processing and Conversion, Product Uses and Distribution, Public Policy
- Workshops will be facilitated by BCS

Regional Roadmap Workshops

- Update Roadmap language
- Incorporate New federal/state activities
  - Renewable Fuels Standards
    - Produce 7.1 million gallons of ethanol by 2012
  - Biofuels Initiative
    - Decrease cost to $1.05 per gallon of ethanol by 2010
    - Displace 40 million gasoline equivalent gallons by 2030
- Revisit path towards achieving Vision Goals
- Invitation only with regional experts
Roadmap Timeline

- Midwest Regional Roadmap
  - Chair: Tom Binder, ADM
  - Chicago, IL, April 11-12, 2006
- West Regional Roadmap
  - Ralph Cavalieri, Washington State
  - Sacramento, CA, August 8-9, 2006
- East Regional Roadmap
  - Douglas Hawkins, Rohm & Haas
  - New York, Fall 2006

Why have a Roadmap?
Where the Fuel Comes From

The top 10 foreign suppliers of crude oil and petroleum products to the U.S., accounting for nearly 50% of consumption between January and November 2003.

<table>
<thead>
<tr>
<th>Country</th>
<th>Barrels Per Day</th>
<th>Percentage of Total U.S. Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>2.1 million</td>
<td>10.4%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1.9 million</td>
<td>9.8%</td>
</tr>
<tr>
<td>Algeria</td>
<td>2.3 million</td>
<td>2.3%</td>
</tr>
<tr>
<td>Iran</td>
<td>1.4 million</td>
<td>1.4%</td>
</tr>
<tr>
<td>Russia</td>
<td>2.0 million</td>
<td>2.0%</td>
</tr>
<tr>
<td>Mexico</td>
<td>1.6 million</td>
<td>7.3%</td>
</tr>
<tr>
<td>Venezuela</td>
<td>1.5 million</td>
<td>7.3%</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1.5 million</td>
<td>5.0%</td>
</tr>
<tr>
<td>Angola</td>
<td>1.1 million</td>
<td>3.3%</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>1.3 million</td>
<td>7.4%</td>
</tr>
</tbody>
</table>

Note: Imports as a percentage of total consumption were computed using January-November 2003 months and consumption data from the Energy Information Administration’s Petroleum Supply Monthly, January 2004.

What is beyond Peak Oil?

Annual Production Scenarios with 2 Percent Growth Rates and Different Decline Methods

- History
- More or 2% Growth and 2% Decline
- More or 2% Growth and 10% Decline
- 7% Growth
- 6% Decline

Note: U.S. assumptions were adjusted to the 1955 foreign unconfined oil inputs worldwide.
Energy consumption in 2050 three times larger than today

Figure 1
US Trade in the Business of Chemistry ($Billions)
What role can biomass play?
According to the EIA:

"The AEO2006 reference case includes only those sections of EPACT2005 (the recent Energy Bill) that establish specific tax credits, incentives, or standards—about 30 of the roughly 500 sections in the legislation."

EIA ethanol production outlook trailing present and scheduled dry mill expansion rate. In 2010, PRX forecast is higher by 1400 mil gal, or about 500 mil bu corn.
Ethanol Use Requirements

- **Law enacted**
- **Legislative Proposals (05-06)**

States Ban MTBE, TBA, and Other Ethers

- **States Banning MTBE / Date of Ban**

As of August 20, 2005
U.S. Ethanol Plants
AS OF: December 2005

Prices of Crude Mineral Oil & Veg. Oils
(all in US - $/barrel)

Daily Prices from 1 Nov 2005 until 23 Jan 2006

*Oil World 28
Biodiesel USA

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (Gal/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1,989,400</td>
</tr>
<tr>
<td>2001</td>
<td>6,437,200</td>
</tr>
<tr>
<td>2002</td>
<td>8,814,600</td>
</tr>
<tr>
<td>2003</td>
<td>18,400,000</td>
</tr>
<tr>
<td>2004</td>
<td>18,900,000</td>
</tr>
<tr>
<td>2005</td>
<td>100,000,000*</td>
</tr>
</tbody>
</table>

Source: CCC Data

*Estimate
US Soy Oil Consumption

• Crop Year 2004 Approx. Production 18.7 B lbs

• 7.5 billion pounds of biodiesel derived from soy oil would represent approximately 40% of current total soy oil demand. This would be 1 billion gallons or 2% of diesel demand.
Figure 1. Switchgrass production regions (switchgrass can be grown in regions other than those included in the analysis, but yield and production practices data are lacking for these regions).

Figure 2. Hybrid poplar production regions (hybrid poplar can be grown in regions other than those included in the analysis, but yield and production practices data are lacking for these regions).
Figure 2. Willow production regions (willow can be grown in regions other than those included in the analysis, but yield and production practices data are lacking for these regions).
Production of CRP Land Converted to Switchgrass at 8.5 Short Tons/Acre (Thousand Dry Tons)

Bioenergy Crops?

What is the short term potential in the Central region?
U.S. Biomass Resource Assessment

- Updated resource assessment - April 2005
- Jointly developed by U.S. DOE and USDA
- Referred to as the “Billion Ton Study”

Crop yields

Source: EUROSTAT, 2004
Yielding potential of energy crops in EU25

Production for Top Four Crops of Each State - 2005 (Thousand Tons)
(Source: Adapted from USDA NASS)
Production (Thousand Tons)

- Corn For Grain
- Hay All (Dry)
- Soybeans
- Corn For Silage
- Wheat All
- Sugarcane
- Sugarbeets For Sugar And Seed
- Sugarbeets For Grain
- Rice All
- Cotton Seed

All Live Tree Biomass 1" dbh and Larger (Thousand Dry Tons)
on Forestland, 2003, 2004
(* = Timberland, 1993, 1994)
Source: USDA Forest Service Forest Inventory and Analysis Data Center
What conversion technologies are available?

Non-Edible Constituents of Biomass

Lignin: 15%–25%
- Complex aromatic structure
- Very high energy content
- Resists biochemical conversion

Hemicellulose: 23%–32%
- Xylose is the second most abundant sugar in the biosphere
- Polymer of 5- and 6-carbon sugars, marginal biochemical feed

Cellulose: 38%–50%
- Most abundant form of carbon in biosphere
- Polymer of glucose, good biochemical feedstock
Edible Constituents of Biomass

**Starch:** 70%–75% (corn)
- Readily available and hydrolysable
- Basis for existing U.S. “biofactories”

**Oil:** 4%–7% (corn), 16%–20% (soybeans)
- Readily separable from biomass feedstock
- Basis for oleochemicals and biodiesel

**Protein:** 20%–25% (corn), 80% (soybean meal)
- Key component of food
- Chemical product applications

Biomass Thermochemical Conversion for Fuels and Chemicals

**Products**
- Hydrogen
- Alcohol
- FT Gasoline
- FT Diesel
- Olefins
- Oleochemicals
- Arrochemicals
- ME

**Producers**
- Hydrogen
- Olefins
- Oleochemicals
- Specialty Chem
Biomass Thermochemical Conversion to Fuels and Chemicals

- Integrate biomass gasification and gas cleanup and conditioning unit operations with existing and developing high pressure fuels synthesis processes
- Leverage a century of C1 chemistry developed for fuels and chemicals synthesis
  - High pressure (10-1000 bar)
  - High temperature (100-500°C)
  - Catalytic
  - Exothermic (thermal control and heat integration)
- Validate syngas quality – gas cleanliness and CO/H₂ ratio

Summary of Syngas-to-Liquids Processes

- Mixed Alcohols
- Fischer-Tropsch
- MTBE
- Acetic Acid
