MORE WOOD. LESS LAND.™

Purpose-Grown Trees as a Sustainable Renewable Energy Source

Short Rotation Crops International Conference

Michael Cunningham
ArborGen, LLC
Agenda

Opportunities for Renewable Energy

The Advantages of Trees

Current and Future Opportunities
Several Drivers are Pushing Bioenergy

- Cost
- Energy Independence and Security
- Rural Development
- Environmental Sustainability
Biomass Feedstock Consumption

Biomass Consumption

<table>
<thead>
<tr>
<th>Biomass Consumption</th>
<th>Million dry tons/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest products industry</td>
<td></td>
</tr>
<tr>
<td>Wood residues</td>
<td>44</td>
</tr>
<tr>
<td>Pulping liquors</td>
<td>52</td>
</tr>
<tr>
<td>Urban wood and food &amp; other process residues</td>
<td>35</td>
</tr>
<tr>
<td>Fuelwood (residential/commercial &amp; electric utilities)</td>
<td>35</td>
</tr>
<tr>
<td>Biofuels</td>
<td>18</td>
</tr>
<tr>
<td>Bioproducts</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>190</td>
</tr>
</tbody>
</table>

Source: EIA 2004

Opportunities for Renewable Energy

Advantages of Trees

Current and Future Opportunities

ArborGen Confidential
The 2007 Renewable Fuels Standard mandates new sources of feedstock are needed. New sources of feedstock are needed in order for the Renewable Fuels Standard to be met. Therefore, renewable sources of cellulosic feedstock must be identified in order for the Renewable Fuels Standard to be met.


#Advanced biofuels includes "cellulosic biofuels" category
Agenda

Opportunities for Renewable Energy

The Advantages of Trees

Current and Future Opportunities
Trees Have Substantial System Benefits

Feedstock Production
- High Productivity Potential (Tons/Acre)

Logistics
- Year-Round Harvest
- Transport
- Storage

Processing
- Multi-Purpose
- High Biomass Quality

Delivered Cost

Opportunities for Renewable Energy
Feedstock Needs are Possible with Trees

Feedstock Requirements

- High Productivity: 10-15+ dry tons/acre/yr, 800-1,500+ gal/acre/year#
- Short Rotation: 5-7 years or less
- Cost Efficient: $35-50/dry ton
- High Quality*: Consistent optimized composition

*Different conversion processes may have different quality definitions
#Assumes 80-100 gallons of EtOH/dry ton of biomass
### Area Needed to Produce 100MM Gallons of EtOH Annually

<table>
<thead>
<tr>
<th>Gallons EtOH/Dry Ton of Biomass</th>
<th>Biomass Needed (dry tons/year)</th>
<th>MAI (dry tons/acre/year)</th>
<th>Rotation Length (years)</th>
<th>Total Acres Needed</th>
<th>Acres Planted Annually</th>
<th>% of Area in Radius 20 Miles</th>
<th>% of Area in Radius 40 Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>1,250,000</td>
<td>10</td>
<td>6</td>
<td>125,000</td>
<td>20,833</td>
<td>28%</td>
<td>4%</td>
</tr>
<tr>
<td>100</td>
<td>1,000,000</td>
<td>15</td>
<td>4</td>
<td>66,667</td>
<td>16,667</td>
<td>15%</td>
<td>2%</td>
</tr>
</tbody>
</table>

**Acres Needed to Produce 100MM Gallons of EtOH Annually**

- **Trees**
- **Annually Harvested Crop**

**Sources:** ArborGen Estimates; Biomass 2 (1982) 75-79
Infrastructure is More Feasible and Efficient

Forest-based feedstocks offer a 15x reduction in transportation infrastructure.
Trees Provide Landowner Flexibility

- Forest Products/Pulp & Paper
- Cellulosic Ethanol
- Direct Firing/Co-Firing
- Gasification/Pyrolysis
- Different wood quality characteristics for various conversion technologies

Advantages of Trees

Opportunities for Renewable Energy

Current and Future Opportunities
Opportunities for Renewable Energy

The Advantages of Trees

Current and Future Opportunities
Global Leader in Tree Improvement

• World’s largest producer of trees for planting.
  ▪ Production, sales and distribution
  ▪ 300+ million annual tree stock sales
  ▪ Extensive customer base
  ▪ Pipeline of world-class elite germplasm

• Today our business spans 20 locations in four countries and includes more than 300 employees
Industry Leading Genetic Resources

- Largest owner of Germplasm in forest industry

- 1st, 2nd, and 3rd generation open-pollinated seedlings
- Elite families
- MCP crosses
- Varietal seedlings
  - a) First large scale production in 2007
  - b) Scale-up to millions is ongoing
ArborGen Opportunities Related to Energy

- BioEnergy Science Center
  DOE-Biofuels
- Scion
  Advanced Biomaterials and Wood Quality
- Wood-to-Ethanol Research
  NCSU – Pulp Mill Re-Purposing
- Eucalyptus Genome
  Next Generation Traits
- Internal Development
  Lignin Reduction
  Stress Tolerance
  Faster Growth
  Wood Quality

Opportunities for Renewable Energy
Advantages of Trees
Current and Future Opportunities
Technology Can Create Significant Value for Landowners

Seedlings
• Elite Pine & Hardwood Material
• Mass-Control Pollinated (MCP) Seed for Improved Performance

Varieties
• Genetic Uniformity
• Increased Productivity
• Improved Product Mix
• Management Efficiency

Value-Enhanced Traits
• Increased Growth Rates
• Shorter Rotations
• Improved Wood Quality
• Breakthrough Applications

Value

Time and Product Testing
Eucalyptus
An Ideal Fiber and Energy Crop

- One of the world’s fastest growing tree species
- Improved through extensive breeding
- Extensive field-testing is building experience in the Southeast
- Growth rates are comparable to those in Brazil

8 Months
3.5-4.5 ft/month

18 Months
Freeze-Tolerance Achieved

- Unable to withstand temperatures in Southeast USA … until now!

Field results from first product indicate freezing tolerance to ~16°F (-8° to -9°C)

Control

Biotech Tree

Lead Lines + Control
Growth Rates Vary by Species

Eucalyptus

Populus (Aspen)

Loblolly Pine

Rotation Length

5 yrs 10 yrs 20 yrs 30 yrs

Growth Rate
Dry Tons/Acre/Yr

15
12
9
6
3

Opportunities for Renewable Energy
Advantages of Trees
Current and Future Opportunities
Faster Growing Hardwoods and Pine are a Reality

- Multiple approaches
- Multiple species

> 100% Volume Gain

Pine

Hardwood

Opportunities for Renewable Energy
Advantages of Trees
Current and Future Opportunities
ArborGen Can Increase Growth and Shorten Rotations

MORE WOOD. LESS LAND.™

Growth Rate
Dry Tons/Acre/Yr

Rotation Length

ArborGen SR Eucalyptus

ArborGen SR Populus

Eucalyptus

ArborGen SR Loblolly

Populus (Aspen)

ArborGen Varietals

Loblolly Pine

Opportunities for Renewable Energy
Advantages of Trees
Current and Future Opportunities
• Trees have numerous feedstock advantages
  ▪ Productivity potential equivalent to alternatives
  ▪ Logistical benefits from year-round harvest
  ▪ Multi-purpose

• ArborGen technology can revolutionize productivity potential
  ▪ Increased yields
  ▪ Shorter rotations
  ▪ Increased environmental adaptability
  ▪ Higher quality wood