Short Rotation Woody Crops as a Component of Woody Biomass Supply

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Role of Woody Biomass

- Renewables contribute about 7% of the U.S. primary energy supply
- Wood is the second largest source of renewable energy in the U.S. after hydro
- Wood supplies about 2% of U.S. energy needs

U.S. renewable energy sources from 1950 – 2009 (EIA 2010)
Woody Biomass Resources

- Variety of sources ranging from forest biomass to harvesting and manufacturing residues to short rotation woody crops (SRWC)
- Multiple sources can be harvested at different times of the year and mixed
  - Limits need for long term storage of feedstocks
  - Consistent year round supply can be maintained
  - Handling and transportation systems developed and in place
  - Just-in-time harvest and delivery
- SRWC and forests are perennial systems with low annual inputs and high potential to generate a broad range of ecosystem services
- In this region SRWC are likely to be part of an integrated supply, not the sole source of material
  - Key SRWC will be shrub willow and hybrid poplar

Sources of Woody Biomass

- Spectrum of systems that can be used to produce woody biomass for biofuels, bioproducts and bioenergy and associated gradients in soil manipulation and silvicultural inputs (After Burger, 2002).
NY Forest Biomass

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Growing Stock</th>
<th>Non-growing stock</th>
<th>Residues</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>10.2%</td>
<td>32.4%</td>
<td>57.4%</td>
</tr>
<tr>
<td>#2</td>
<td>11.8%</td>
<td>33.9%</td>
<td>54.3%</td>
</tr>
</tbody>
</table>

- 4.8 million odt/year
~ 3X current harvest rates

(Wonjar et al. 2010)

NY Potential Biomass Production

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Forest</th>
<th>Perennial Grasses</th>
<th>Woody Crops</th>
<th>Corn Stover</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>2.1</td>
<td>0.3</td>
<td>2.3</td>
<td>4.8</td>
</tr>
<tr>
<td>#2</td>
<td>3.3</td>
<td>6.4</td>
<td>4.6</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Potential biomass production (million odt/yr) in NY from different sources in two scenarios (Wonjar et al. 2010)
Technically Available Woody Biomass Supply

- Determine amount of technically available woody biomass from forests and willow biomass crops available in 80 km radius around Lyonsdale, NY

80 km radius woody supply shed around Lyonsdale, NY (Castellano and Volk 2008)
Technically Available Woody Biomass from Forests

- Over 606,000 ha of forest cover
- Remove forest land:
  - preserves
  - excessive slope
  - small parcels
  - classified wetland
- ~ 363,000 ha of timberland
- Potential production of 422,000 odt per year
  - 79% of 80 km radius assessment

Timberland within the 80 km road network around Lyonsdale, NY (Castellano and Volk 2008)

Technically Available Woody Biomass from Agricultural Land

- 209,000 ha of agricultural land cover
- Remove land:
  - not classified for agriculture
  - excessive slopes
  - wetlands
  - small parcels
- ~ 101,000 ha remaining
- On 10% of this land (10,000 ha) could produce 112,000 odt/yr

Agricultural land in a 80 km radius around Lyonsdale, NY (Castellano and Volk 2008)
Technically Available Woody Biomass Supply

- Available land includes
  - 363,000 ha timber land
  - 101,000 ha agricultural land
- A total of 534,000 odt of woody biomass is technically available
  - 422,000 from timber land
  - 112,000 from willow crops
- Willow biomass crops grown on a land area that is 2.8% of the timberland area could produce 22% of the total biomass

Willow Biomass Crops

- Over 350 species of willow in the world
- Shrub willows are the main focus (>175 species)
- Pioneer species adapted to marginal conditions
- Coppicing ability
  - One planting, up to seven harvests
- Rapid growth and canopy closure
- Yields of fertilized and irrigated unimproved clones have reached 27 odt ha⁻¹ yr⁻¹ (Adegbidi et al. 2003)
Willow Biomass Production Cycle

Site Preparation

Planting

First year growth

Harvesting

Early spring after coppicing

Coppice

Three-year old after coppice

Location of Willow Biomass Crop Trials
Economics of Willow – Base Case

- Improve economics by increasing yield, optimizing harvesting systems, and improving crop management, and producing multiple products from each ton of biomass

NPV: ~ $116/ha  IRR: 5.5%  (Buchholz and Volk, in press)

Willow Production Cost Structure

Source: Buchholz and Volk 2010
SRWC Harvester Development

- Harvesting is the single largest cost of producing willow biomass crops
- Dormant season, single pass cut and chip harvesting system based on New Holland (NH) forage harvester
- Trials since 2005 with Case New Holland forage harvester and specially designed cutting head
- Latest trials in willow and hybrid poplar indicate that this system is effective and can harvest stems up to 15 cm in diameter

New CNH Short-Rotation Coppice header being tested in western NY in early 2009

Moving Chips to the Edge of the Field

- Self-unloading forage wagons
- Forage blower
- Covered over-the-road trailers (30-36 tons of chips)
Moving Chips to the Edge of the Field

- Forage dump wagon
- Large forage dump wagon
- Open top over-the-road trailer (25-30 tons of chips)

Effect of Increased Yield

- With a base case yield of 12 odt ha⁻¹ yr⁻¹, the internal rate of return is ~ 5.5%.
- A 50% increase in yield more than doubles the IRR.
- Improve yield through:
  - breeding and selection
  - Improved crop management including weed control, matching clones to sites, nutrient management, spacing, rotation length etc

Effect yield on IRR of willow biomass crops (Buchholz and Volk 2010)
Willow Biomass Crops - Yields

- First rotation yields are 10 - 13 odt/ha-yr
  - Second rotation yields will be 15-20% higher
- New varieties have 15-30% greater yield than check varieties
- Breeding for yield, pest and disease resistance and form

Results from first yield trials with 13 new willow varieties at two locations in NY (Volk et al. unpublished data)

Policy Incentives

- Growing willow biomass crops with the assistance of the BCAP establishment grant and annual incentive payments would increase the internal rate of return in the base case scenario to close to 40%
- Even with low yielding sites (6 odt ha⁻¹ yr⁻¹) IRR would be close to 10%
  - Extensive planting with poor establishment and poor yields will probably stall out the development of SRWC once the incentives are removed
  - This is the pattern that occurred in Sweden in the 1990s
Price for Biomass

- Generating more value from the feedstock should raise the price for the feedstock
- Increasing price can have a dramatic effect on IRR for willow biomass crops

Effect of changes in the price for willow biomass on the crops IRR (Buchholz and Volk 2010)

Woody Biomass

(Liu 2008)
Wood Based Biorefinery

- Evolutionary Change - Wood cost at $60-100 per dry ton ($0.03-0.05/dry pound) and extraction at 20% of mass with 2/3 as sugars and 1/3 as acetic acid/extractives
- Sugars at $0.10/pound and acetic acid/extractives at $0.50/pound - .06 + .17 = $0.23/lb.
- Produces $92 odt\(^{-1}\) value for the 400 pounds extracted, which is most of the feedstock cost
- Residue converted to pellets for heat and power, paper or other solid wood products with a feedstock with little or no cost with 20% of the mass removed
- Trials have been completed with various hardwoods and varieties of willow
The Future for SRWC

- SRWC are in their infancy in terms of development and deployment
- Need to improve the economics of SRWC
  - Increase yield through genomics, breeding and selection
  - Optimizing production systems in relation to weed control, nutrient management, density, rotation length
  - Improving harvesting systems to lower these costs
  - Increasing the value of a ton of woody biomass

Distribution of costs for willow biomass crops over five 4-year rotations (Buchholz and Volk 2010)
The Future for SRWC

- Potential for increasing multiple benefits from SRWC systems including biodiversity, soil and water quality
- Integrating SRWC into the landscape will enhance these benefits
- Combine SRWC with other woody biomass sources to provide consistent flow of feedstock
- Need to increase the value of woody biomass by making a wider range of products from each ton

Questions