Developing Willow Biomass Crops as a Source of Home Grown Energy

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Willow - Regional Background

- Onondaga County was the center of the U.S. willow basket industry in the early 1900s
- ESF initiated willow biomass research in 1986

Hubbard, W. 1904.
Why Willow?

• High biomass production potential
• Easily established with unrooted cuttings
• Resprouts vigorously after each harvest
• Wide range of genetic variability
• Limited insect and pest problems
• Over 40,000 acres of commercial plantings in Europe
• Over 1,000 acres planted in U.S. already with more planned in 2010 in other states
  – Over 25 yield trials in U.S. and Canada

Three-year old willow in Tully, NY
Location of Willow Biomass Crop Trials

Legend

- ■ Active Biomass Sites
- ■ Previous Biomass Sites
- ■ Phytoremediation Sites

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What Willow?

- Focus is on the development of shrub type willows, not the more conspicuous tree willows
- Varieties selected do not root sucker or spread easily

Weeping willow (*Salix babylonica*)
Willow Biomass Production Cycle

- **Site Preparation**
- **Planting**
- **Coppice**
- **First year growth**
- **Early spring after coppicing**
- **Three-year old after coppice**
- **One-year old after coppice**

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Planting Equipment

- The only commercial willow planters in the US are in NY
- Step planter introduced to US in 1999 by SUNY – ESF
- Egedal planter introduced to the US in 2008 by Dennis Rak from DoubleAWillow
- Manufactured in Europe so support and parts are difficult to obtain
- Working with local manufactures to have planters built in central NY for the North American market

Two styles of European planters being used in NY – the Step Planter and the Egedal.
Three Year Old Willow Biomass Crops
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 indicate that this system is effective and can harvest stems up to 6 inches in diameter

New CNH Short-Rotation Coppice header being tested in western NY in early 2009
Moving Chips from the Edge of the Field

Self-unloading forage wagons

Forage blower

Covered over-the-road trailers (30-36 tons of chips)
Moving Chips from the Edge of the Field

Forage dump wagon

Large forage dump wagon

Open top over-the-road trailer (25-30 tons of chips)
Global Carbon Cycles

100% Carbon Closure
(Assumes 0.25 t/ha-yr increase in soil carbon)

CO2 Recycled

Feedstock Production (62%)
Transportation (12%)
Power Plant Construction (26%)

Natural Gas
1.00 → 0.40

Net CO2 Emissions: 0%

Corn Ethanol
1.00 → 1.67

(Mann and Spath 1997, Heller et al. 2003)
Bird Diversity in Willow

Andre Dhondt – Laboratory of Ornithology
Cornell University

Peter Wrege – Cornell University
Willow Cash Flow Model

An Economic Analysis Tool for
Willow Short-Rotation Coppice Plantations
for Wood Chip Production

Project Name
Location
Acres (min. 20) 20

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(Available to download from http://www.esf.edu/willow/download.asp/)
Willow Biomass - Economics

- Cash flow model for willow biomass crop production and delivery to end user
- Allows for input parameters to be set by each user
- Includes all components of willow crop production from site preparation to delivery of biomass to end user
  - Land rental
  - Site preparation
  - Planting, maintenance and harvesting
  - 25 mile delivery of willow biomass
  - Multiple harvests over 22 years
  - Removal of willow crop at end of 20 years
  - Assumes a $30/green ton price at the plant gate
  - 4 year harvest cycle
Economics of Willow – Base Case

Yearly cash flow in $ per acre

US $/acre (undiscounted)

Year
Economics of Willow – Base Case

Accumulated cash flow in $ per acre

- Realistic
- Optimistic (Revenues +10%; Expenditures -10%)
- Pessimistic (Revenues -10%; Expenditures +10%)

Year

US $/acre

NPV: $209/acre   IRR: 6.4%
Distribution of Costs

- **Stock removal**: 740 $ ha\(^{-1}\)
- **Transport**: 1,179 $ ha\(^{-1}\)
- **Harvest**: 3,778 $ ha\(^{-1}\)
- **Fertilizer**: 1,225 $ ha\(^{-1}\)
- **Establishment**: 2,709 $ ha\(^{-1}\)
- **Administration**: 276 $ ha\(^{-1}\)
- **Land cost and insurance**: 1,955 $ ha\(^{-1}\)

(Buchholz and Volk, in review)
Commercial Planting Stock Production

- Double A Willow, Fredonia, NY
  - More than 100 acres of willow nursery beds planted with varieties from SUNY ESF breeding and selection program since 2005
    » Includes seven clones that have been awarded patents
  - Sold about 2 million cuttings in 2009 for biomass crops and for other applications
  - Projected production of 30 million cuttings in 2010

Shrub willows in nursery beds at Double A Vineyards, Fredonia, NY (www.doubleawillow.com).
Impact of Establishment Costs

- Planting stock accounts for 60 – 80% of establishment costs
- Planting stock costs have almost been cut in half with production in a commercial nursery (DoubleAWillow.com) compared to earlier scale up production at SUNY-ESF

Changes in establishment costs and IRR with changes planting stock costs
Effect of Increased Yield

- With a base case yield of 5 odt ac\(^{-1}\) yr\(^{-1}\) internal rate of return is \(\sim 6\%\).
- 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, in review)
Shrub Willow Breeding Program

- Since 1998, more than 600 crosses attempted

26 families of *S. purpurea*

101 families of *S. eriocephala*

91 other families, mainly *S. sachalinensis, S. miyabeana*
Increased Yields from Breeding and Selection

New varieties contribute to 21% greater yield

(Tully ‘05 and Belleville ‘05 Cameron et al., unpublished data. Other sites from Kiernan et al. 2003)
Economics of Willow – With BCAP
$40/ac for 5 years rental rate and 75% establishment cost share

NPV: $940/acre   IRR: 30%
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.
Current Wood to Energy Facilities

- Hemicellulose
- Cellulose
- Lignin

Renewable Heat and Power
Or
Renewable Power
Wood to Energy Biorefinery

- Acetic acid
- Ethanol
- Biodegradable plastics
- Chemicals
- Renewable Heat and Power

Hemicellulose: (15 – 20% of mass)

Cellulose

Lignin
Wood chips after two hours

Extract solution after two hours
Multiple Products from Wood

- After extraction:
  - Darker color
  - Structure still intact
  - Cellulose and lignin maintained
  - Same volume and shape
  - 20-23% lower mass
  - Lower ash content
  - Higher energy content
Multiple Products from Biomass

- Higher lignin content gives these pellets greater structural strength with fewer nub
- Ash content is premium grade even from wood with bark
- Removal of hemicellulose makes wood less likely to reabsorb water
Multiple Products from Biomass

Submerge an extraction pellet & a conventional pellet in water

1 minute

15 minutes

Extracted pellet still in tact

60 minutes
Multiple Products from Biomass

Then, air dried for 24 hours

Extraction pellet still in tact

Conventional pellet disintegrated
Existing and Proposed Bioenergy, Biofuels and Biorefinery Facilities in Central New York

**Legend**

- Existing
- Proposed or in Construction
- Future

- < 5 MW - 15 Mile Supply Radius
- 5-20 MW - 30 Mile Supply Radius
- > 20 MW - 50 Mile Supply Radius

This map shows biomass power/Cellulosic ethanol facilities either in operation, under construction or proposed for the Central New York Region. The rings show the anticipated biomass supply radii serving each facility.

Map prepared at SUNY-ESF by Philip J. Castellano Aug 2009

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Summary

• Need to change our energy use patterns and sources of energy
• Biomass has the potential to provide a unique range of renewable energy products
• Willow biomass crops grown on marginal agricultural land will contribute to the biomass supply in the region
• Need to develop value added products from each ton of biomass
Now is the Time for Action

- “The stone age did not end for lack of stone, and the oil age will end long before the world runs out of oil.”
  – Sheikh Zaki Yamani, former oil minister for Saudi Arabia

- "We must be the change we wish to see."
  ~M. Ghandi
Colleagues and Collaborators

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  - Dr. Ed White

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