Commercializing Willow Biomass Crops for Bioenergy and Bioproducts in the Northeastern and Midwestern United States


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Colleagues and Collaborators

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  – Cornell University - Michigan State University
  – Middlebury College - Montreal Botanical Gardens
  – SUNY Delhi - University of Connecticut
  – University of Guelph - University of Minnesota
  – University of Saskatchewan

• Industrial Partners
  – Agricultural Development Services - AgroEnergie - Antares Inc.
  – Case New Holland - Catalyst Renewables - Double A Willow
  – Honeywell International - Mesa Engineering - O'Brien and Gere
Overview

• A brief history of willow in the U.S.

• Hurdles on the track to commercialization of willow biomass crops
  – Misperceptions about biomass
  – Economics of the systems
  – Infrastructure to support willow deployment
  – Lack of experience and understanding for large scale implementation
  – Markets: The chicken and egg question
  – Lack of policy support to launch new biomass production and use systems

• Expansion of alternative cover technology
History of Willow in U.S.

- Large basket willow industry from mid 1800s – early 1900s
- First trials assessing shrub willow for biomass production in U.S. planted in 1986
  - Started with plant material and collaboration with the University of Toronto

Willow rods being prepared for basket production in the early 1900s (Hubbard 1904)
History of Willow in U.S.

- 1995 – begin collections of native willow for breeding and selection program
- 1998 – 2000 - large scale (~500 acres) demonstration of willow biomass crops in central and western NY (DoE BPRD program)
- 1998 – first crosses of shrub willow for biomass production
- 2003 – initiation of research to develop an alternative cap on the Solvay waste beds in central NY
- 2003 – establishment of living willow snow fence demonstrations
History of Willow in U.S

- 2005 – first trials with the New Holland forage harvester in willow biomass crops in North America
- 2005 – first plantings of willow in nursery for commercial scale production of planting stock.
- 2006 - first commercial willow plantings in US by Catalyst Renewables
- 2008 – Initiated 10 acre pilot demonstration for alternative landfill for the Solvay waste beds
Willow Biomass Production Cycle

**Site Preparation**

**Planting**

**Harvesting**

**Coppice**

- Three-year old after coppice
- One-year old after coppice
- Early spring after coppicing
- First year growth

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Three Year Old Willow Biomass Crops
Challenges to Commercialization of Willow

• The people factor
  – Misperceptions about biomass
  – What is sustainability

• Economics of the systems
  – High up front establishment cost
  – Yields and low prices for biomass
  – High harvesting costs

• Infrastructure to support willow deployment
  – Large amount of planting stock (typical planting density is 5,800 plants acre⁻¹)
  – Equipment for planting and harvesting
  – Lack of experience and understanding for large scale implementation
  – Need for consistent and ongoing R&D support for energy crops
  – Near and long term markets
  – The chicken and egg question
  – Higher value products from willow and woody biomass

• Policy support to launch new biomass production systems
Bioenergy Systems are Complex

Bioenergy systems are complex due to the interplay between natural systems, agricultural land, short rotation coppice, degraded land, and the community watershed. Solar energy and atmospheric carbon are inputs to the system, while products from hunting and gathering, agricultural residues, and woody biomass are outputs. Conversion technology is used to generate usable power, and maintenance is required for community resources. Wastewater and atmospheric emissions are also significant outputs. Decisions are made at various points in the system, affecting the flow of goods and services to the outside community, which includes (agricultural) goods, capital, technology, training, and political power.
Bioenergy Systems are Complex

Agricultural land

Degraded land

Natural systems

Agricultural residues

Products from hunting and gathering

Ecosystems

Atmospheric carbon

Solar energy

Short rotation coppice

Ash

Wastewater?

Soil & Biodiversity loss

Atmospheric emissions

Decision points

Outside community

Community watershed

Natural resource management

Community

Human population

Technology, Training, Political power

(Agricultural) Goods, Capital, Goods, Capital

Decision points

The People Factor
Impact of the People Factor

- Misperceptions about biomass
  - Value laden, emotionally charged issues
  - Need for good scientific evidence to address concerns
  - Need for long term discussions with concerned groups

- Lack of stakeholder involvement and participation, especially at the local level
  - 1/3 of biomass projects in the UK in the late 1990s failed because of local opposition (Upreti 2004)
  - 2/3 of small scale gasifiers deployed in India were not in operation after one year
  - Local opposition stops wood bioenergy project in Oneonta, NY
  - CREP policy support for establishing willow biomass crops in NY is derailed

Preliminary engineering for 35MW wood fired facility in Oneonta, NY
Sustainability

• A concept that is based on human values, perceptions and political interests associated with environmental, economic and social components of a system
• A directional, rather than absolute, measure because it is based on human values that will change over multiple scales of time and space
• Differences in values often result in disagreements on criteria and mechanisms to assess sustainability
• Need to develop agreed upon mechanisms to assess the concept
Welcome to EcoWillow v.1.0 (Beta)

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

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We acknowledge support of NYSERDA, USDA CSREES, and the State of New York, Dept. of Agriculture and Markets

(Available to download from http://www.esf.edu/willow/download.asp/)

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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
Economics of Willow – Base Case

Yearly cash flow in $ per acre

US $/acre (undiscounted)

-1,500 -1,000 -500 0 500 1,000

Year

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Economics of Willow – Base Case

Accumulated cash flow in $ per acre

NPV: $209/acre  IRR: 8%
Distribution of Expenses over 22 Years

Cost shares in %, undiscounted

- Stock removal: 14%
- Transport: 24%
- Harvest: 31%
- Fertilizer: 3%
- Establishment: 3%
- Administration: 18%
- Land cost and insurance: 7%

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Commercial Planting Stock Production

- Double A Willow, Fredonia NY
  - More than 40 hectares of willow nursery beds planted since 2005
  - Produced about 5 million cuttings in 2007/08 for biomass crops and for other applications
  - Projected production of 15 million cuttings in 2008/09
  - Future production potential of about 30 million cuttings

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

- Establishment costs in Europe have decreased by 30-50% as area planted to willow increased.
- U.S. is benefitting from many of the learned lessons so reductions may not be as steep, but there are gains to be made.
- 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.
Impact of Establishment Costs

• Mechanization and optimization of planting stock production, harvesting, processing and storage can further reduce costs

• Other areas where establishment costs could be reduced include
  – proper field layout to optimize harvesting over multiple rotations
  – increasing planting efficiencies
  – optimization of site preparation
  – reduction in planting density
  – reduction in equipment staging costs when more acreage is planted in a given region

Willow whip harvesting machines being developed for nursery crops by AgroEnergie (red) and Double A Willow (yellow)
Planting Equipment

- Step planter introduced to US in 1999 by SUNY – ESF
- Used to plant over 1,200 acres in the US and Canada
- Planted over 500 acres in 2008
- Manufactured in Sweden so support and parts are difficult to obtain
- Working with local manufactures to have units assembled in US

Step planter being used to establish willow biomass crops in northern NY in the spring of 2008
Egedal planter introduced to the US in 2008 by Dennis Rak from DoubleAWillow

- Heavier planter with fewer moving parts
- Not effective on wet soils, but otherwise plantings were successful this spring
- Limited experience and data on effectiveness in North American conditions

Egedal planter being used to establish willow biomass crops in western NY in the spring of 2008
Impact of Establishment Costs

• Lack of experience and understanding of willow crop production results in establishment problems

• Cutting corners on site preparation results in higher not lower establishment costs!
  - Paying rent for a year to control perennial weeds may cost $25 – 40 /acre
  - One post emergence herbicide application can be $60 – 80/acre

Limited control options result in outbreaks of hard to control weeds like yellow nut sedge
Commercial Plantings Installed by Catalyst Renewables

[Map showing commercial plantings in different counties with details such as "Rick Lucas & Family 36 Acres Lewis County," "Tim LeVan 36 Acres Lewis County," "Barry Cranston 36 Acres Lewis County," "Walter Anges 48 Acres Oneida County," "Lyle Merri 83 Acres Oneida County," "Edgewood Farms 110 Acres Livingston County," and "W.W. Patterson Farms 98 Acres Cayuga County."]
Harvester Development

- Dormant season, single pass cut and chip harvesting system based on New Holland (NH) forage harvester
- Trials over the past two years with a NH forage harvester and specially designed cutting head
- CNH is developing a new Short-Rotation-Coppice (SRC) header
- Initial field trials were run in the UK in March 2008
- Field trials planned for the US, UK, Belgium and Germany in the winter of 2008/2009
Effect of Increased Yield

- Yield increase has a significant impact on IRR
- Base case scenario includes 10 odt ha\(^{-1}\) yr\(^{-1}\) in first rotation and 12 odt ha\(^{-1}\) yr\(^{-1}\) in subsequent rotations

Effect yield on IRR of willow biomass crops
New Yield Trials Now Established on 12 Sites

- Edmonton, AB (2006)
- Saskatoon, SK (2007)
- Montréal, QC (2007)
- Escanaba, MI (2007)
- Middlebury, VT (2007)
- Waseca, MN (2006)
- 5 locations in NY (2005-2007)
- Also in 2007: Loughgall, N. Ireland (2007)
Policy Incentive Options

• Need for support to develop industry to a level where benefits from economy of scale occur
  – CRP, CREP or biomass crop assistance program (BCAP)
• Consistent and reliable support for R&D
  – Number of questions and unknowns increases as commercialization begins
  – Need to be able to respond quickly to resolve problems
    » news of failures travels quickly
    » multiple successes are required to change the perceptions generated from a single failure
Economics of Willow – With CRP

$35/ac for 10 years rental rate and 50% establishment cost share

Accumulated cash flow in $ per acre

NPV: $942/acre    IRR: 20%
Incentives

- Investment is about $900/acre
  - $550/acre establishment grant + $35/acre for ten years
- Potential biomass production
  - @ 5 odt acre$^{-1}$ yr$^{-1}$ for 20 years = 100 odt
    » Cost is $9.00/odt or about $4.50 per green ton
- What acreage is needed to begin to capture economies of scale
  - Use 40,000 acres as an example
- Incentive cost for 40,000 acres over several years is $36,000,000
- Small cost to launch a new home grown source of renewable energy that has the potential to generate hundreds of new jobs, reduce greenhouse gases, generate taxes, increase landscape biodiversity etc.
Market Developments

Combined Heat and Power

Co-firing

Biorefinery

Gasification

Small Scale Heat
Wood Based Biorefinery

- Commercial pilot wood based biorefinery at Lyonsdale Biomass CHP plant in upstate NY with
  - 25 dry tons per day of hardwoods from forests and willow biomass crops
  - Annually produce
    » 130,000 gallons of ethanol
    » 6,000 tons of acetic acid
  - extracted chips have a higher energy density and significantly lower ash content
    » Beneficial for CHP, pellet production, used for generation of renewable power
Central New York Biorefinery

• $10.3 million grant awarded in December 2006 from NY Agriculture and Markets
Wood to Energy Biorefinery

Water Extraction

Acetic acid
Hemicellulose
Cellulose
Lignin

(15 – 20% of mass)

Ethanol
Biodegradable plastics
Chemicals

Renewable Heat and Power
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 = $.23/lb.
- Produces $92 odt\(^{-1}\) value for the 300 pounds extracted, which is most of the feedstock cost
- Residue converted to heat and power with a feedstock cost with little or no cost with 20% of the mass removed
- Trials have been completed with various hardwoods and varieties of willow
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
Alternative Applications for Willow

- Success with willow has prompted interest in alternative applications
- Over 700 acres of Solvay waste beds that are 45 – 60 ft deep
- High pH, high salt concentration, limited structure
- Project goals:
  - Reduce percolation that is carrying salts into surrounding surface and groundwater
  - Produce a biomass product that can be used for the production of bioenergy
- Project started in 2003 by screening willow varieties
- Field trials and monitoring start in 2004
- Installed the first 10 acre pilot demonstration area in 2008
Willow Trials on the Settling Basins

Three years of growth of willow biomass crops on Solvay waste amended with biosolids
Pilot Demonstration Area
Conclusions

• Significant amounts of progress have been made over the past 20+ years
• Transition to a commercial crop has begun, but there are many challenges ahead if this is going to be a viable enterprise
• Alternative uses for willow will help to support and develop it application as a biomass crop
• Remember the people factor in each stage of the system
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