Overview

1. Woody Biomass & Bioenergy
2. Shrub Willow Biomass
3. Willow operations in Northern NY
4. Environmental Benefits
5. Alternative Applications
Biomass and Bioenergy

**Biomass** = material (mass) from plants (bio)

**Bioenergy** = energy from the sun stored within biomass

- **Agricultural Biomass Crops**
  - Corn, soybeans, seed crops

- **Herbaceous Biomass Crops**
  - Switchgrass, *Miscanthus*, ag residues

- **Woody Biomass Crops**
  - Fire wood, forest residues
  - Short rotation woody crops...
  - Poplar, southern pine, shrub willow
Woody Biomass in Society

United States Energy Use

Renewables
- 9% of total supply

Wood
- 22% of renewables
- Second largest source

BioEnergy (biofuels + wood)
- 43% of renewables

(EIA, 2011)
Woody Biomass in Society

Potential Biomass Supply

600 Million Dry Tons

- From energy crops by 2030
- Large increases
- Large percentage of total

(USDOE Billion Ton Update, 2011)
Forest Biomass Potential

2011 Study (SUNY ESF)
- ReEnergy Lyonsdale
- Biopower facility
- 50 mile radius (road network)

1.5 million acres of forest
- 900,000 suitable for biomass
- Excludes preserves, wet, etc

Forest Biomass Potential...
- 425,000 dry tons per year
- Mean annual increment
- Residues from logging
Woody Crop Potential

2011 Study (SUNY ESF)
- ReEnergy Lyonsdale
- 50 mile radius (road network)

500,000 acres of ag land
- 250,000 suitable for biomass
- Excludes slopes, prime ag land, etc

Woody Crop Potential...
- 25,000 acres (10%)
- Relatively small land area
- 5 odt/ac/yr
- 125,000 odt/yr

+500,000 odt/yr forests + woody crops
- 50 mile radius around one facility
Willow Biomass Program

Research on shrub willow since 1986
• Crop development
• Breeding programs
• Yield improvement
• Economic analysis
• Best practices
• Sustainability
• Multiple uses/benefits

Commercialization of shrub willow for biomass energy and alternative applications
Willow Biomass Program
Willow Genus (*Salix* spp.)

**Shrub willow**

*Salix purpurea*, *Salix miyabeana*, *Salix sachlinensis*, *Salix viminalis*, *Salix eriocephala*, *Salix caprea*...

...and many cultivars of these species

Not tree willows!

*(Salix babylonica)*
Shrub Willow

Unique plant characteristics

Numerous applications

Woody energy crops

Hardwood biomass

5 dry tons/acre/year

or

10 wet tons/acre/year
Shrub Willow Biomass Energy Crops

Forestry
• Woody plants
• Hardwood biomass
• Perennial species
• Multi-year harvest cycle

Agriculture
• Agricultural lands
• Agricultural machinery
• Cultivation practices
• Intensive crop management
Why Willow?

Can be grown on lower quality soils...

Marginal land - Not profitable for ag in current markets

1 million acres statewide - poorly drained, wet soils

Target Idle Farm Land

• Tap underutilized resource
• Rural development
• Productive ecosystems
• Not compete with food
Why Willow?

Wide Genetic Diversity
• Over 350 species world-wide

Highly Adaptable
• Large geographic range
• Various site conditions

Ecological Stress Tolerance
• Flooding
• Cold
• Pests and diseases
Why Willow?

**Rapid Growth Rates**
- Hardwood biomass 10 – 15 times faster than local forest

**Easy Establishment**
- New roots and shoots
- Unrooted stem cuttings

**Coppice Ability**
- Plant once – harvest seven times

**Environmental Benefits**
- 40,000 acres in Europe
Unrooted Stem Cuttings
Mechanized Planting
Double-Row Pattern

5,500 plants per acre
75% survival rate

2.5 foot Row spacing
6 foot Alley Spacing
2 foot Plant Spacing
A Few Weeks Later
End of First Growing Season
Coppice
Mid-Summer
Five to ten feet per year
Three Years After Coppice
Large Woody Stems
1 to 2 inch diameter
Mechanized Harvesting
Chip Transfer
Biomass Feedstock
Biomass Heat and Power
Cut Stools
The Following Spring
Repeat seven times
Barriers to Commercial Willow

- High start up costs - $1,000/acre
- Intermittent cash flows
- Long payback periods
- Uncertain markets
- Status quo bias
- Specialized machinery
USDA Biomass Crop Assistance Program

“Improve domestic energy security, reduce carbon pollution, and spur rural economic development”

“...provide assistance to land owners to establish, produce and deliver biomass feedstocks.”
Biomass Crop Assistance Program

Catalyze commercial adoption and innovation...

- Partial establishment grants
  - Offset high start up costs

- Land rental payments
  - Non harvest years

- Purchasing contracts
  - With biomass end user
New Willow Plantings (800+ acres)

Early adopters and innovators

Celtic Energy Farm and individual landowners

Crops est. 2013, coppiced after first grow season

Now one year-old stems

Two year-old root system
New Willow Plantings (800+ acres)
BCAP Planting Video
Spring 2014
August 2014

Majority 800 acres is 4 to 8 feet tall
Minor weed and pest issues addressed
First harvest on schedule in next 2 to 3 years
Mature Willow Plantings (300+ acres)

Planted four to five years ago

100+ acres harvested in 2013

200+ to be harvested in 2014

Total nearly 1200 acres

Harvests every year
Mature Willow Plantings (300+ acres)
Willow Harvesting

New Holland self propelled forage harvester - 130FB header

Developed by New Holland Agriculture from 2008 - 2012

Tested in commercial-scale trials by SUNY ESF 2012

Efficient harvesting platform – now commercially available
Harvesting Video
Willow Extension Services

Training and education for BCAP willow...

- Technical assistance
- Outreach programs
- Crop monitoring
- Equipment access
- Analytical tools and research summaries
ReEnergy LLC

BCAP “project sponsor” for NY Willow

Biopower company - facilities throughout the northeast

11 year purchasing contracts with growers

Mixing willow with forest residue chips

Renewable electricity

Integrated/complimentary feedstock supply chains
Biopower 2013

2,500 tons of chips harvested from BCAP fields

ReEnergy Lyonsdale - mixed with forest residue chips

1400 Mwh of renewable electricity from willow (5% gen)
Willow Chip Quality

Low variability commercial feedstock

Meets end user specifications

Mixing with forest reside chip for biopower

2013 harvest samples

Previous research samples
**Moisture Content**

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<th>2013 Commercial Harvest</th>
<th>2012 Commercial Trials</th>
<th>Previous Research Trials</th>
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<td>43%</td>
<td>45%</td>
<td>44%</td>
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<td>Stan Dev</td>
<td>± 2%</td>
<td>± 2%</td>
<td>-</td>
</tr>
<tr>
<td>Range</td>
<td>35% – 55%</td>
<td>37% - 52%</td>
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**Ash Content**

<table>
<thead>
<tr>
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<th>2013 Commercial Harvest</th>
<th>2012 Commercial Trials</th>
<th>Forest Residue Chips</th>
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<td>Average</td>
<td>3.0%</td>
<td>2.6%</td>
<td>~2%</td>
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<tr>
<td>Stan Dev</td>
<td>± 0.7%</td>
<td>± 0.6%</td>
<td>-</td>
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<tr>
<td>Range</td>
<td>2% - 4%</td>
<td>1% - 3%</td>
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Energy Density

<table>
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<th>2013 Commercial Harvest</th>
<th>2012 Commercial Trials</th>
<th>Forest Residue Chips</th>
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<tr>
<td>btu/lb (dry)</td>
<td>8,240</td>
<td>8,200</td>
<td>8,200 - 8,600</td>
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</table>

- Overall chip quality similar to forest residues chips
- Meets end user specs
- Suitable for mixing feedstocks
Multiple Pathways

Biopower

Co-firing

Gasification

Combined Heat & Power

Biorefinery
Multiple Products and Biproducts
Hot Water Extraction

- **Harvested Chips**
- **Heat, Water, Pressure**
- **Extracted Chips (Cellulose & Lignin)**
  - **Hemicellulose (15 - 20% of mass)**
  - **Organic Chemicals**
  - **Biodegradable Plastics**
  - **Acetic Acid**
  - **Ethanol**
  - **Renewable Heat & Power**
Environmental Benefits

Carbon Neutral Lifecycle...

• Net-zero GHG emissions
• Does not contribute to climate change
• CO$_2$ sequestered above and below ground
• Offsets +100% of emissions
• Production, harvesting, transport, end-use
• Construction of biopower facility
Environmental Benefits

Bird and Wildlife Habitat...

• Increases cover and habitat
• Mid-succession (shrubland)
• Birds and small mammals
• Ideal nesting habitat
• Rare and native song birds
Environmental Benefits

Net-energy Ratio (Energy Return on Investment)...

Takes Energy to Make Energy!

Important Sustainability Metric for Renewable Energy

Willow Net Energy Ratio...
- Between 15:1 and 45:1
- Depends on transport & end-use
- One unit in, 15 - 45 units out

Other Renewable Energy Sources
- Wind - 20:1
- Solar PV - 10:1
- Corn Ethanol - 5:1 or less
Jobs and Rural Development

10,000 acres of bioenergy crops...

- 40 - 50 direct jobs + 20 - 30 indirect/induced jobs
- Biomass production transport and end-use

(NYSERDA, 2010)(Proakis et al. 1999)

Keeps energy dollars and jobs local!
Economics of Production

EcoWillow 2.0....

- Lifecycle cash flow model
- Willow biomass crops
- ESF (2008)
- Recently updated
- Latest data
- Commercial operations
Economics of Production

EcoWillow 2.0....

Improved Base Case Scenario..
- IRR - 5%
- Payback - 13 years
- Production Costs - $25/ton$_{\text{wet}}$

BCAP Improved Scenario...
- IRR - 20%
- Payback - 7 years
- Production Costs - $20/ton$_{\text{wet}}$

Returns on Investment are Improving...
- Continued research
- Commercial innovations
- Incentive programs for early adopters
Alternatives Applications of Shrub Willow
Living Willow Snow Fences

Installed along roadways across New York State

Traps blowing snow in drifts, before it reaches the road
Living Willow Snow Fences
Living Willow Snow Fences

Reduce Cost of Snow Control
• $2.3 billion annually in the US
• $300 million annually in New York State

Improve Road Safety
• Driving conditions
• Accidents rates
• Save lives

Provide Additional Benefits
• Travel time savings
• Environmental benefits
• Aesthetics
• Value-added products
Streambank stabilization

Prevent drastic erosion and flooding

Native habitat for shrub willow

Quickly colonize a site
Landscape & Ornamental

- Aesthetic value
- Wet and muddy areas
- Privacy hedges
- Noise and visual screens
- Living willow sculptures and art
Bioremediation & Bioengineering

Use plants to do work of machines & industrial processes....

- Water filtration
- Soil remediation
- Erosion control
- Protective structures

Same plant traits as bioenergy..

- High growth rate and biomass production
- Tolerance of high planting density
- Coppice ability
- Fibrous root system
- Wide range of ecological tolerances
- High rates of transportation
- Low nutrient requirements
**Bioremediation & Bioengineering**

Restoration of former industrial sites (phytoremediation)

Vegetative land fill caps (evapotranspiration cover)

Waste water treatment (municipal and ag. wastes)

Vegetated buffers

Other pollution controls

And more...
Multiple Benefits

The best willow systems produce numerous benefits...

Example...

Solvay Settling Basins, Syracuse, NY.
Solvay Settling Basins

Settling Basin 13

Settling Basin 14

Settling Basin 12

Settling Basin 15

Town of Camillus C&D Landfill

Warner's Road

Gare Lock Road

Rt. 695
Solvay Settling Basins

Large industrial dumping ground

Decades of waste, now in the clean up stage

Close proximity to Onondaga Lake, Nine Mile Creek

Threat to local watershed and wildlife

High pH (salty) runoff

Now being remediated with shrub willow...
Solvay Settling Basins
Solvay Settling Basins

Willow is able colonize and thrive in harsh conditions

Grows in industrial waste with minor amendments

Stabilizes soil and prevents runoff from the site

Acts a vegetative landfill cover

Now over 100 acres established
Solvay Settling Basins

Numerous benefits from a single system...

1. Alternative landfill cap - cheaper and more effective

2. Willow biomass - same rate and quality as mineral soils

3. Protecting local watershed and ecosystems

4. Documented increase in wildlife, habitat and biodiversity

5. Community demonstration project and planned recreation (Nature trails, bird watching, etc)

Former industrial dump rejuvenated into community asset
Summary

Woody biomass is an important part of our renewable energy mix and America’s energy future.

Shrub willow is a promising source of woody biomass.

Years of research... now commercial adoption and innovation.

Sustainable, locally produced energy, rural development and environmental benefits.
Willow Short Course

Two Day Event...

Tuesday November 18th
• One day conference at SUNY-ESF
• New Gateway Center
• Numerous speakers
• Tours of ESF biomass systems

Wednesday November 19th
• Willow harvesting demonstration
• Location TBA

Registration...
• $50 including meals
• www.esf.edu/willow
Thanks for your attention!

Questions?

SECOND ANNUAL • October 22, 2014

National Bioenergy Day
Celebrating Nature’s Energy Source

www.esf.edu/willow