

# Shrub Willow

## Woody Biomass & Bioenergy



SECOND ANNUAL • October 22, 2014



# National Bioenergy Day

*Celebrating Nature's Energy Source*

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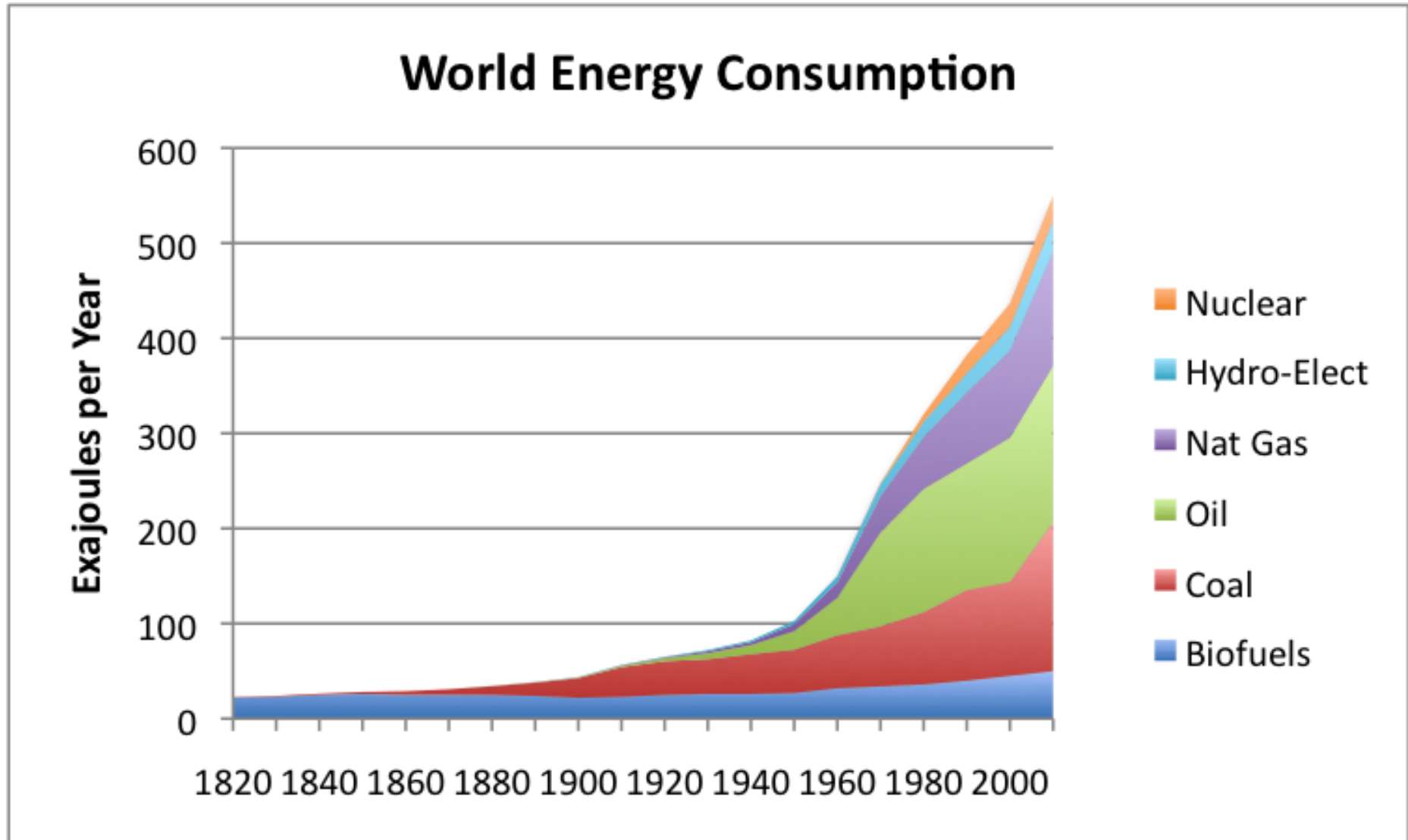


State University of New York  
College of Environmental Science and Forestry

# Overview

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

# Energy in Society



# 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**

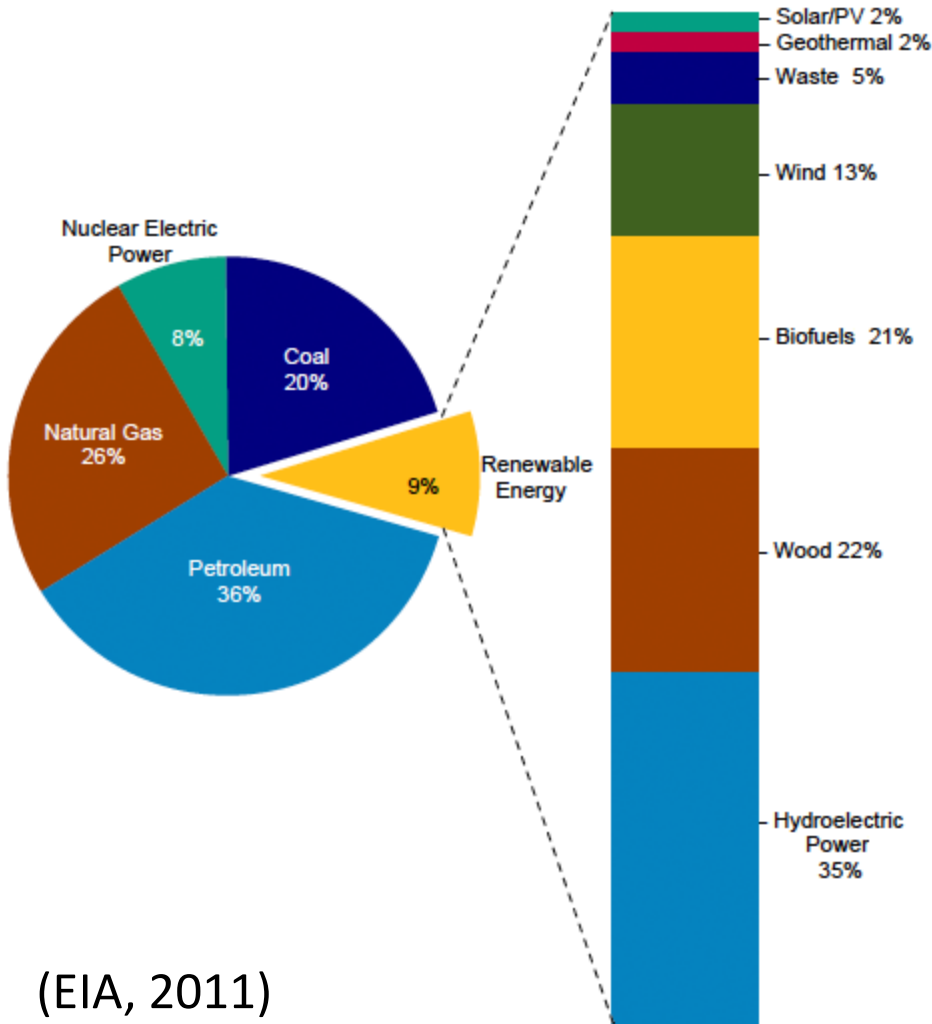
- Fire wood, forest residues
- Short rotation woody crops...
- Poplar, southern pine, shrub willow





# Woody Biomass in Society

## United States Energy Use



(EIA, 2011)

## Renewables

- 9% of total supply

## Wood

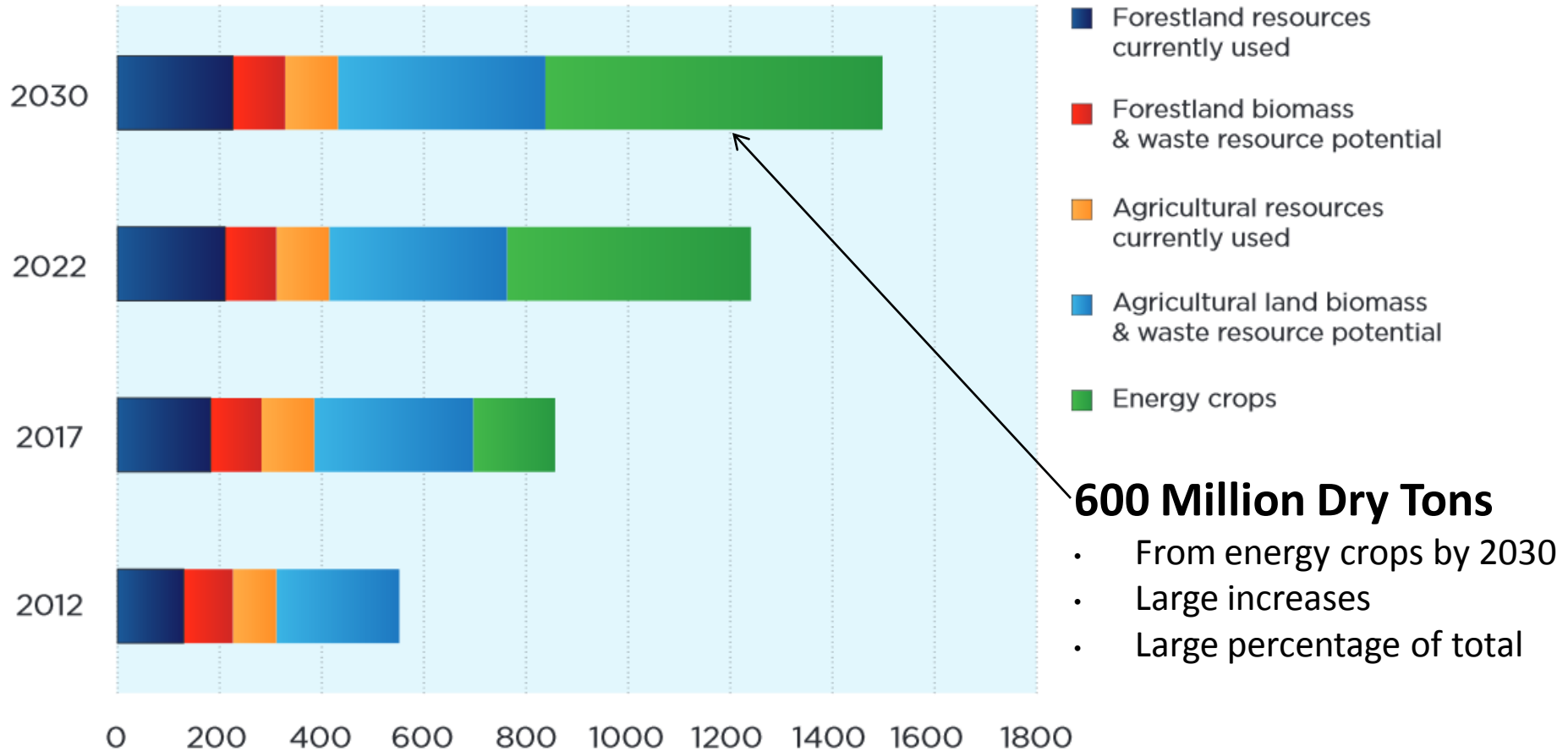
- 22% of renewables
- Second largest source

## BioEnergy (biofuels + wood)

- 43% of renewables

# Woody Biomass in Society

## Potential Biomass Supply



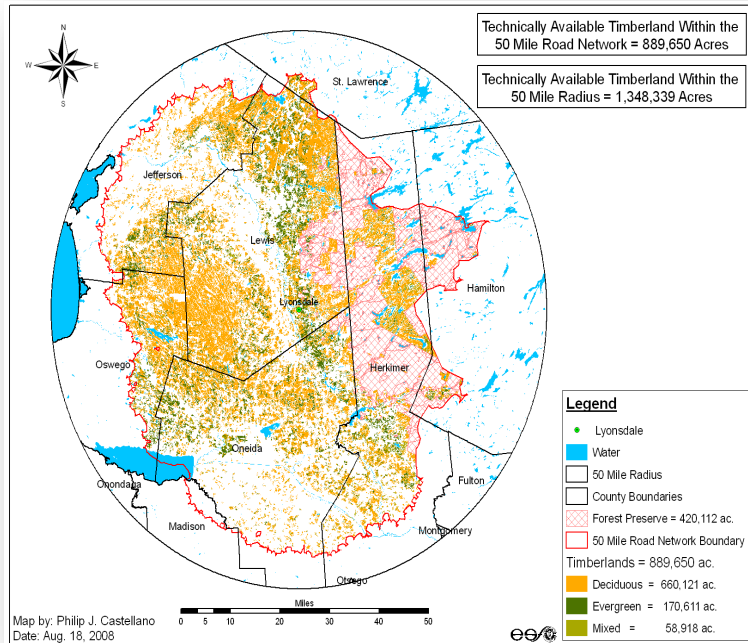
**600 Million Dry Tons**

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

Million dry tons

(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

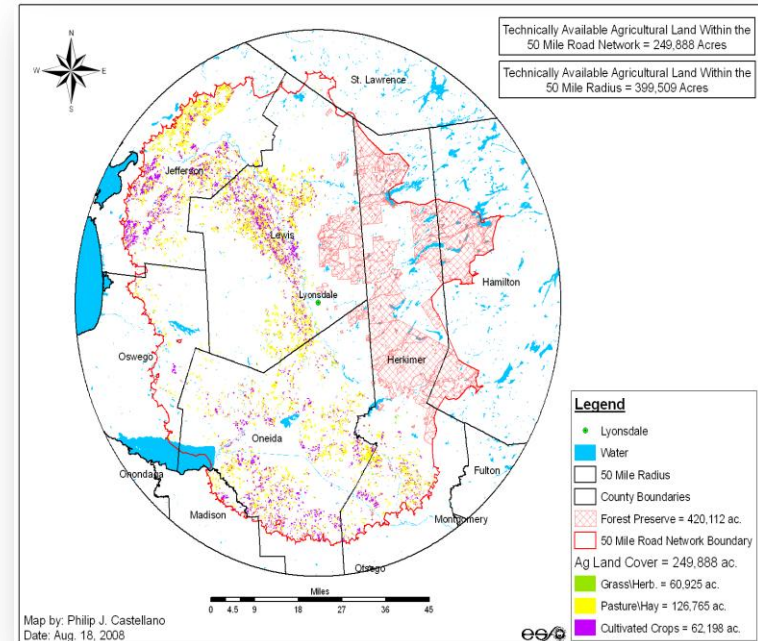
- 250,000 suitable for biomass
- Excludes slopes, prime ag land, etc

## 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



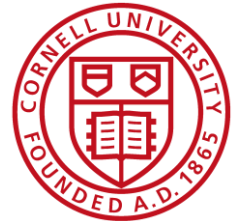
**Commercialization of shrub willow  
for biomass energy and alternative applications**

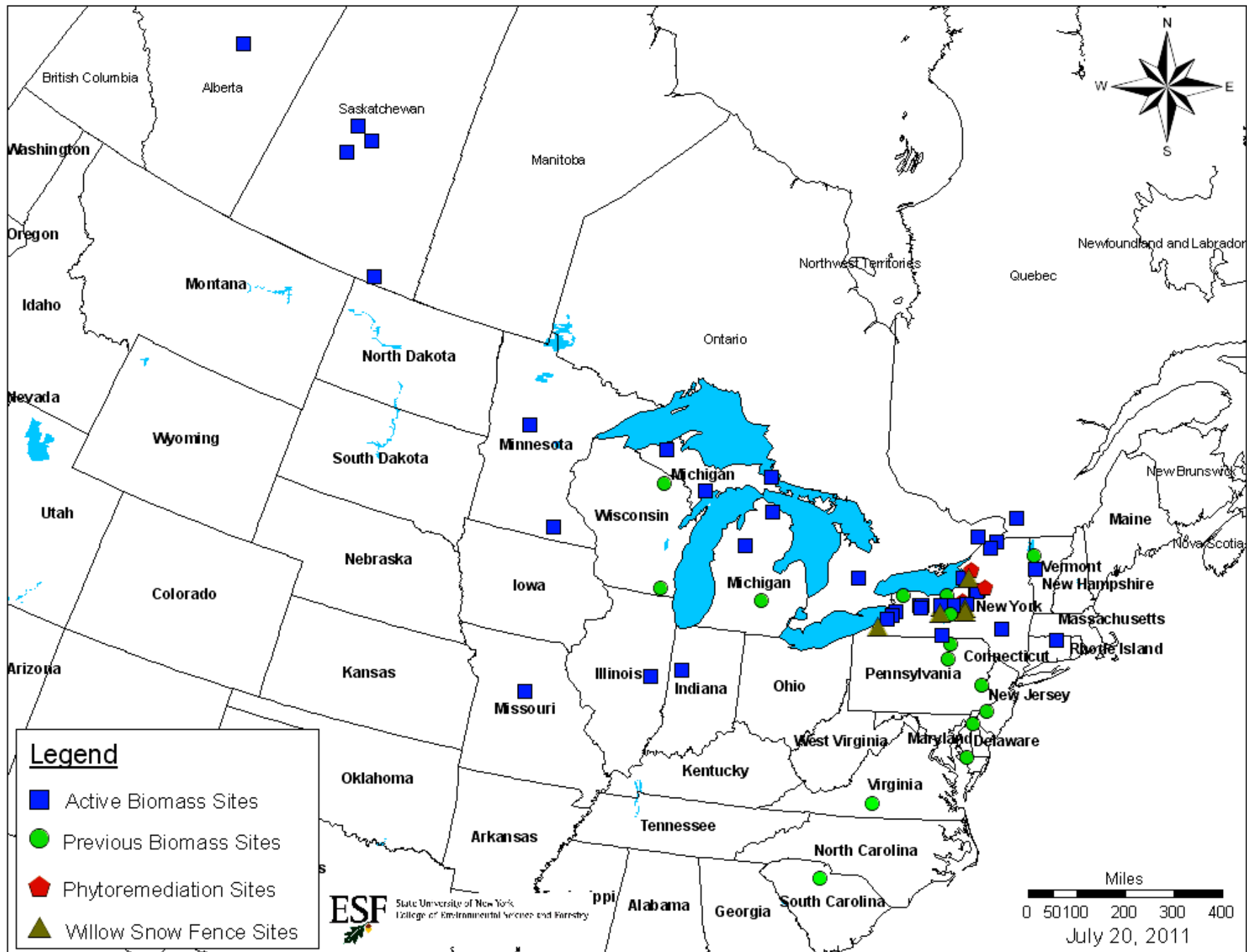


# Willow Biomass Program



U.S. Department of Transportation





# 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**



## Forestry

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



## Shrub Willow

Biomass Energy Crops



## 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



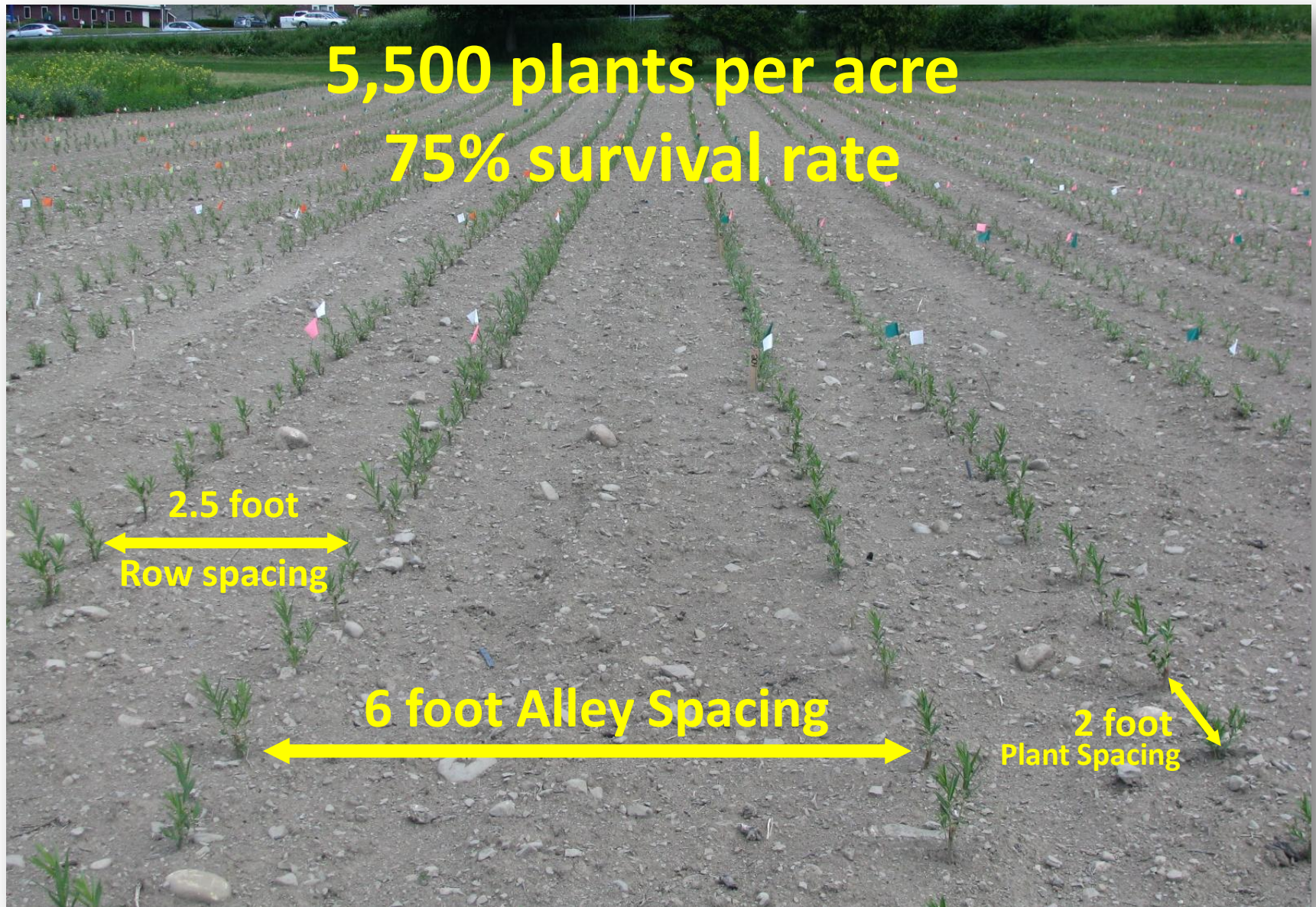


# Mechanized Planting





# Double-Row Pattern





# Just Planted



# 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





Site Preparation



Planting



Coppice (cut-back)



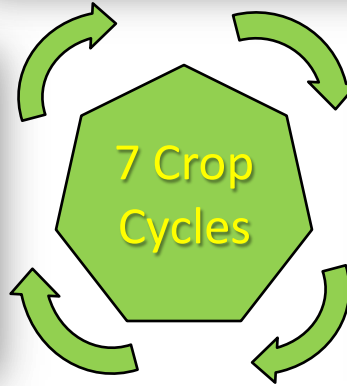
Three Years Growth



Minor Maintenance



7 Crop Cycles



Harvest Biomass



Seven Harvests

Rapid Regrowth



15 dry tons/acre each harvest



One Crop Establishment





# 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

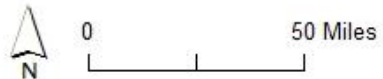
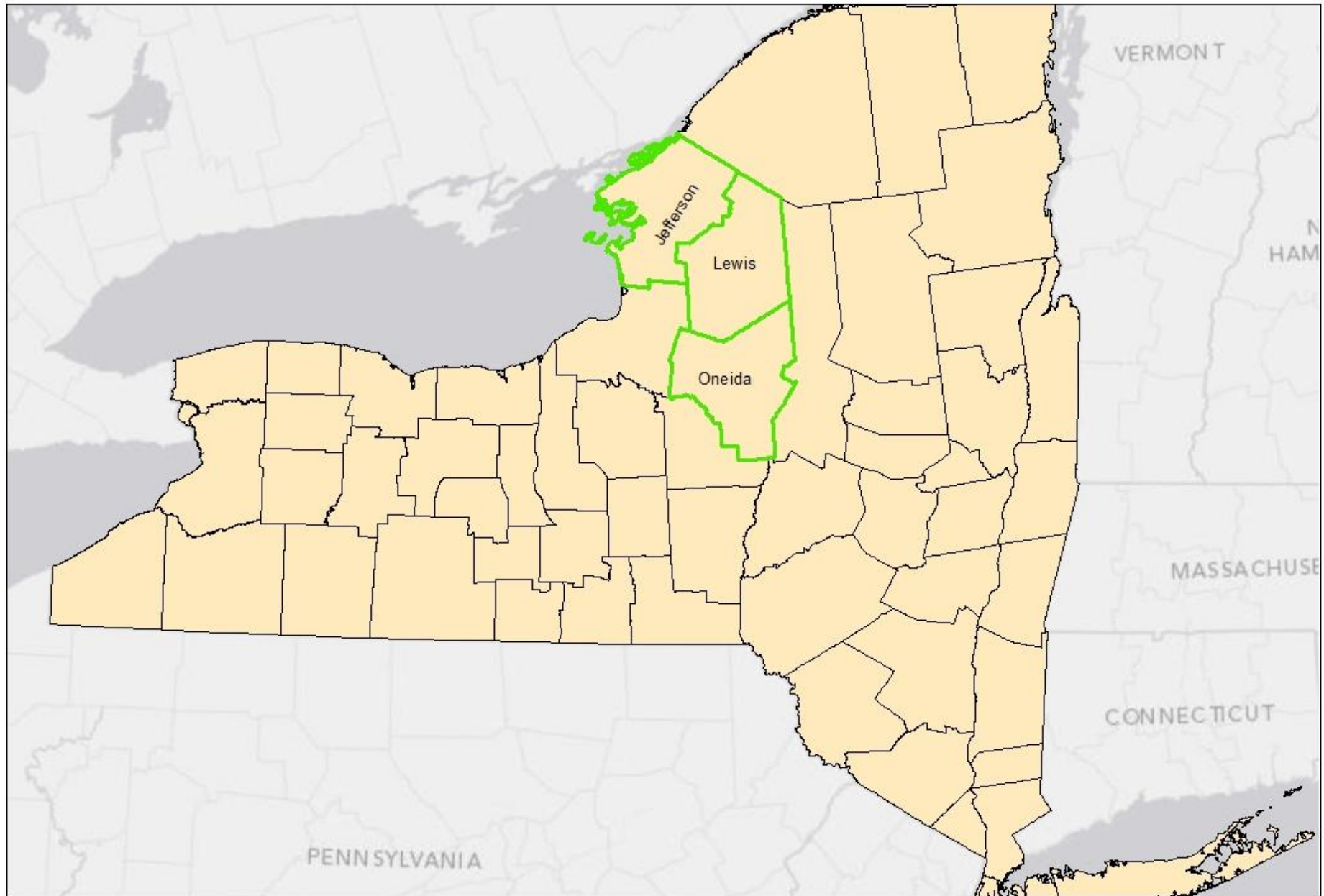
Catalyze commercial adoption and innovation...

- **Partial establishment grants**
  - Offset high start up costs
- **Land rental payments**
  - Non harvest years
- **Purchasing contracts**
  - With biomass end user



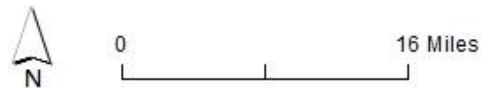
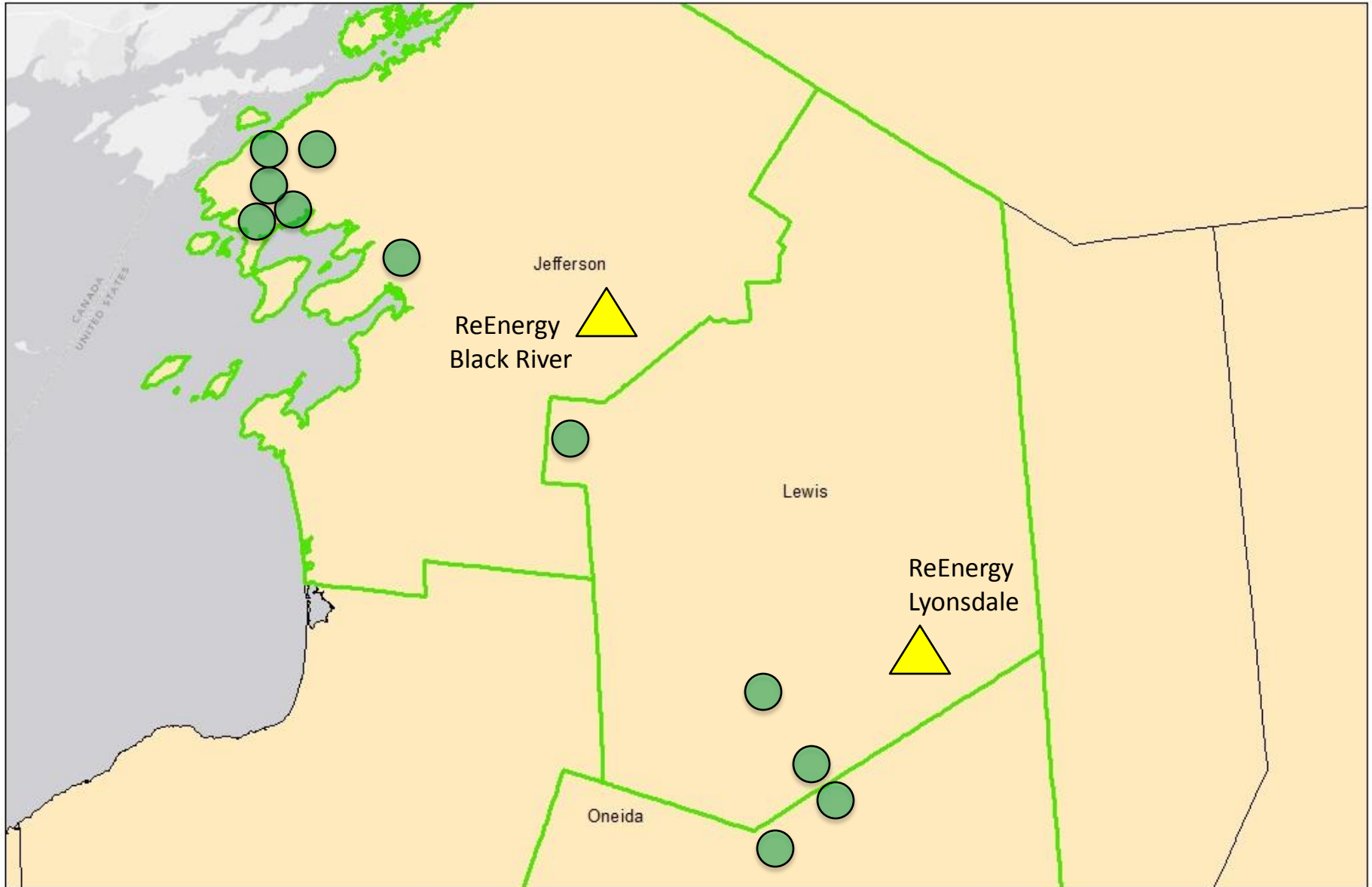
Committed to the future of rural communities.

# New York State Counties with Commercial Willow Production





# New York State Counties with Commercial Willow Production



 Willow Production Area

 Biopower Facility

# **New Willow Plantings (800+ acres)**

**Early adopters and innovators**

**Celtic Energy Farm and individual landowners**

**Crops est. 2013, coppiced after first grow season**

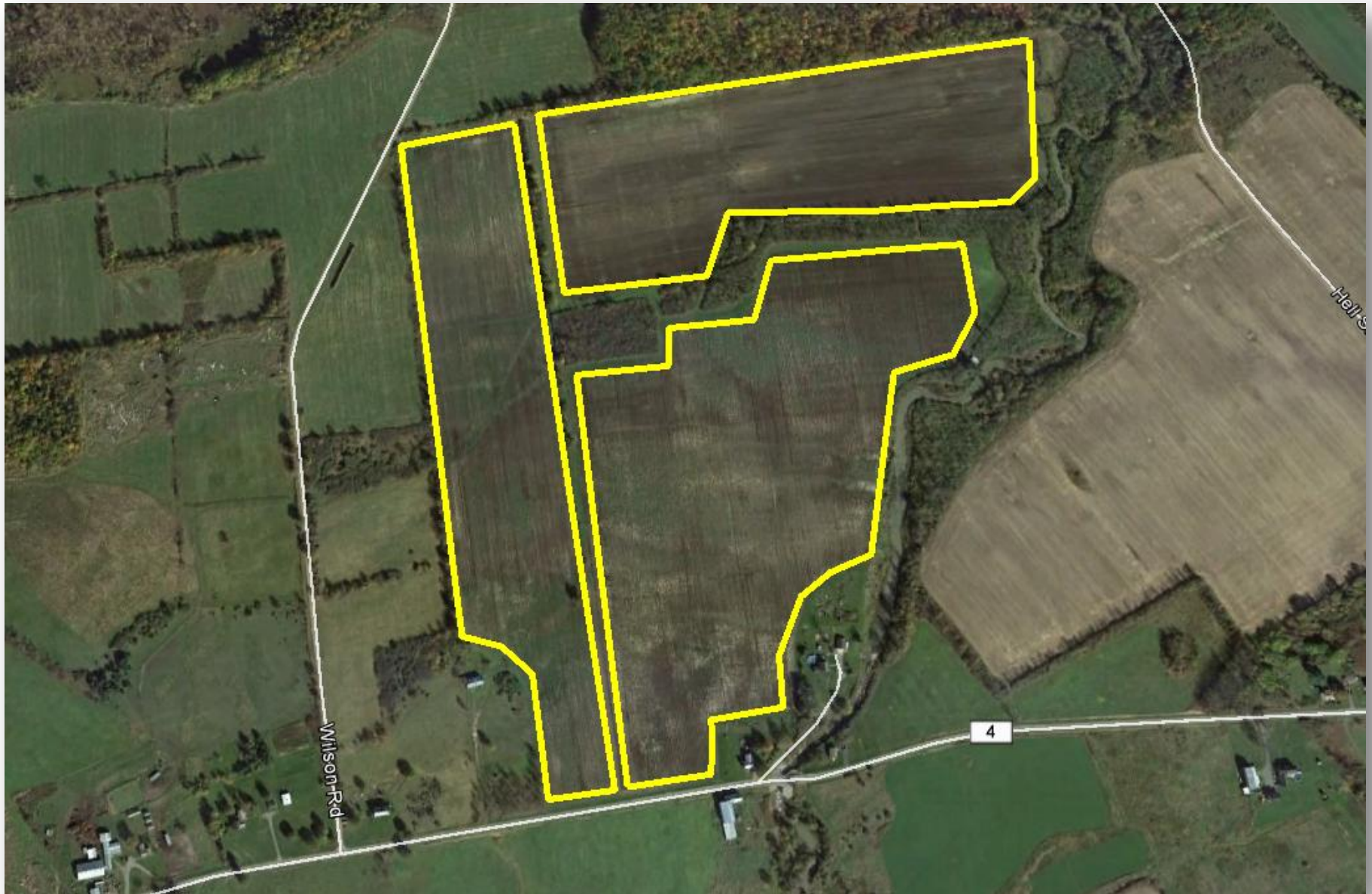
**Now one year-old stems**

**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**

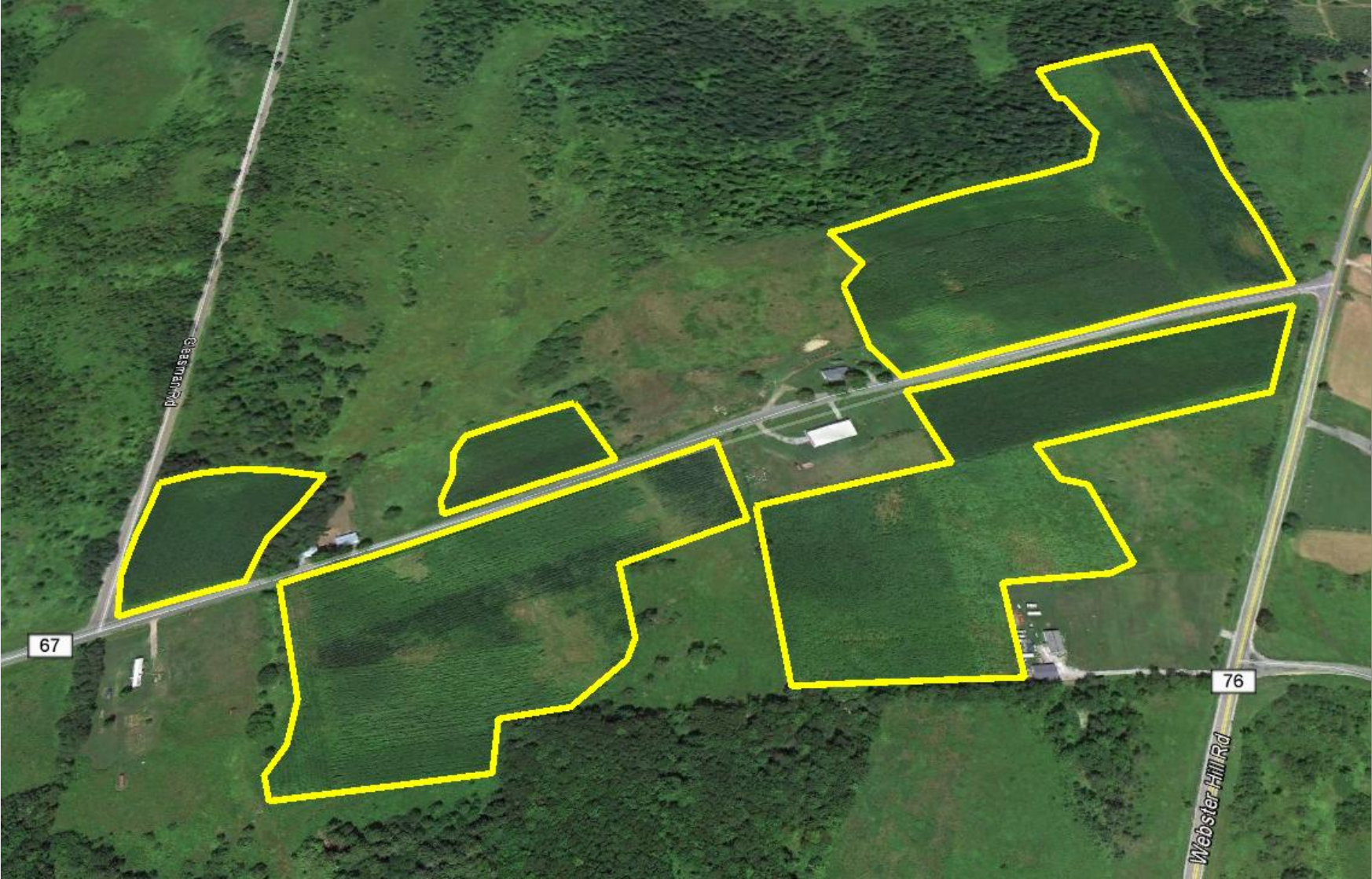
**200+ to be harvest in 2014**

**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 residue chip for biopower**

**2013 harvest samples**

**Previous research samples**





# Moisture Content

	<u>2013</u> Commercial Harvest	<u>2012</u> Commercial Trials	Previous Research Trials
Average	43%	45%	44%
Stan Dev	± 2%	± 2%	-
Range	35% – 55%	37% - 52%	-

# Ash Content

	<u>2013</u> Commercial Harvest	<u>2012</u> Commercial Trials	Forest Residue Chips
Average	3.0%	2.6%	~2%
Stan Dev	± 0.7%	± 0.6%	-
Range	2% - 4%	1% - 3%	-

# Energy Density

	2013 Commercial Harvest	2012 Commercial Trials	Forest Residue Chips
btu/lb (dry)	8,240	8,200	8,200 - 8,600

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





# Multiple Pathways

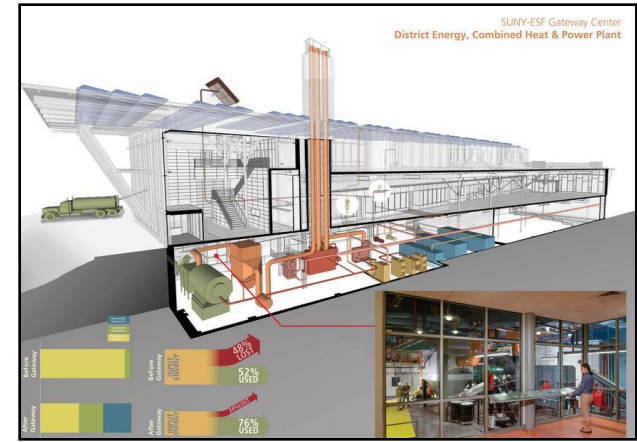
## Biopower



## Thermal



## Combined Heat & Power



## Co-firing



## Gasification



## Biorefinery





# Multiple Products and Biproducts





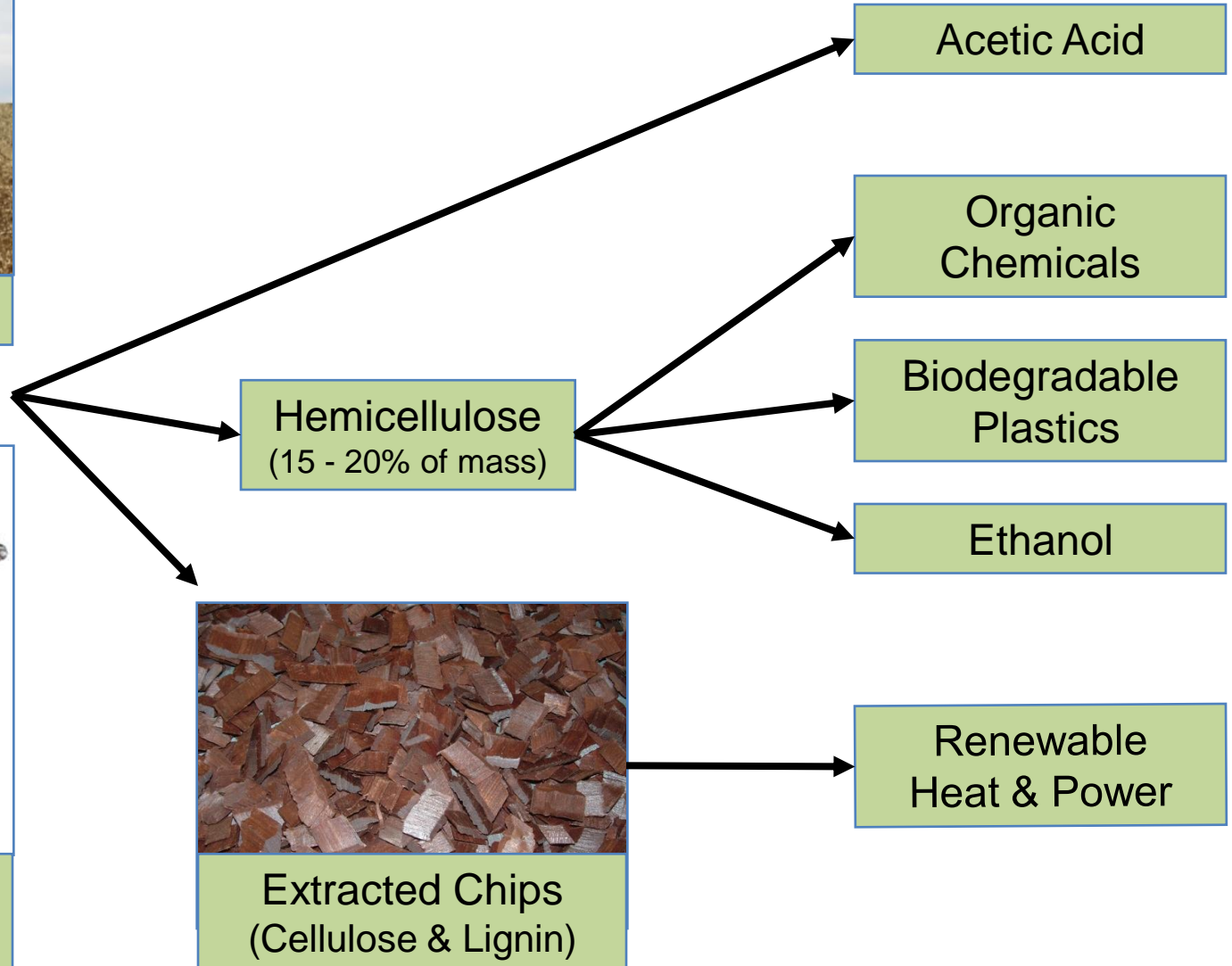
# Hot Water Extraction



+



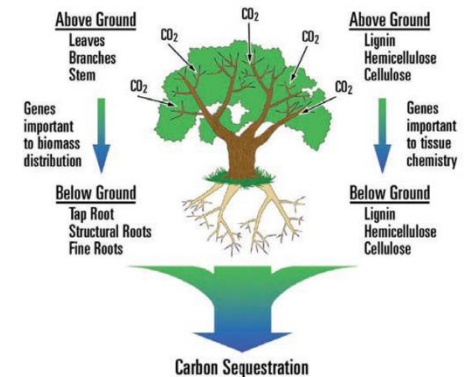
Heat, Water,  
Pressure



# Environmental Benefits

## Carbon Neutral Lifecycle...

- Net-zero GHG emissions
- Does not contribute to climate change
- CO<sub>2</sub> 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!**

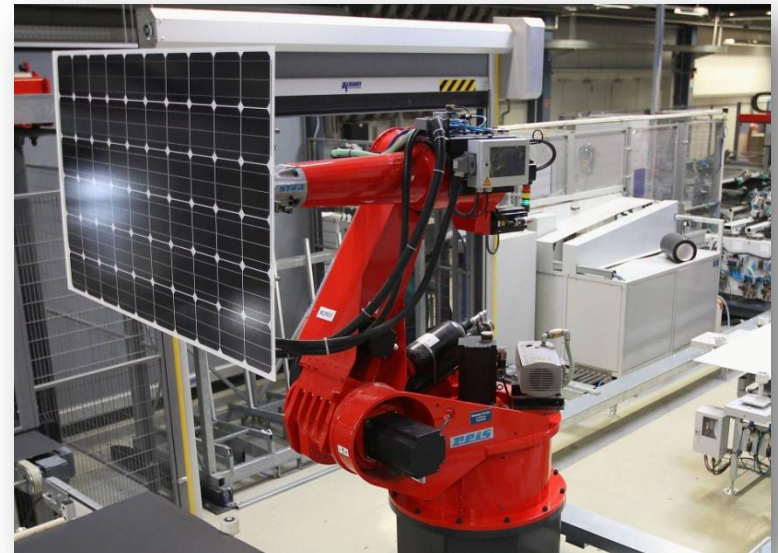
**Important Sustainability Metric for Renewable Energy**

**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



### Model Input-Output

Model Inputs		Suggested Value 2014	
<b>General data</b>			
Total field area (from Fields module)	ac	100.0	-
Total planted area (from Fields module)	ac	50.0	-
Average annual biomass yield (wet)	tons/ac/yr	10.5	10.0
Crop rotation length (harvest cycle)	yr	3	3
Interest rate	%	5.00%	5.00%
Land costs (tax, lease, insurance)	\$/ac/yr	30	30
Internal administration costs	\$/ac/yr	5	5
Biomass price at plant gate (wet)	\$/ton	23.00	27.50
Stock removal at project end	\$/ac	400	400
Moisture content at harvest (for dry outputs)	%	45%	45%
<b>Incentive Program</b>			
Years of enrollment in incentive program	yr	11	11
Annual average incentive payments (AP)	\$/ac/yr	0	40
Percentage of AP paid in harvest year	%	0%	0%
Biomass incentive co-payments (wet)	\$/ton	0	0
Establishment grants received	\$/ac	0	100
<b>Crop Establishment</b>			
Vegetation removal (brush hogging)	\$/ac	20	20
Contact herbicide	\$/ac	20	20
Plow	\$/ac	20	20
Rock picking and site improvements	\$/ac	0	0
Disc	\$/ac	20	20
Plant cover crop	\$/ac	10	10
Kill cover crop	\$/ac	30	30
Planting costs (from Plant tab)	\$/ac	\$598	-

Model Outputs		Economic Time Frame	
		13 yrs	22 yrs
<b>Financial analysis</b>			
NPV (Net Present Value)	\$	\$176,740	\$3,643
NPV optimistic (R=10%; E=10%) <sup>a</sup>	\$	\$23,457	\$61,625
NPV pessimistic (R=10%; E=10%) <sup>a</sup>	\$	(\$59,892)	(\$66,527)
IRR (Internal Rate of Return)	%	1.9%	5.4%
IRR optimistic (R=10%; E=10%) <sup>a</sup>	%	8.8%	11.7%
IRR pessimistic (R=10%; E=10%) <sup>a</sup>	%	-6.2%	-5.0%
<sup>a</sup> R = Revenue E = Expenses			
<b>Production costs and revenues</b>			
Annual production costs per acre	\$/ac/yr	\$240	\$235
Annual gross revenue per acre	\$/ac/yr	\$218	\$273
Annual net revenue per acre	\$/ac/yr	\$19	\$39
Production cost per ton (wet)	\$/ton	\$26.60	\$24.59
Break-even price (including incentives)	\$/ton	\$26.00	\$24.59
Biomass price at plant gate (wet)	\$/ton	\$26.00	\$26.00
Net revenue per ton (wet)	\$/ton	\$1.40	\$3.41
<b>Dry outputs (0% moisture)</b>			
Total startup costs prior to first harvest	\$	\$36,966	
Startup costs per acre	\$/acre	\$1,065	
Costs for one commercial harvest	\$	\$22,713	
Production costs per ton (dry)	\$/ton	\$48.36	\$44.71
Harvest costs per unit biomass (dry)	\$/ton		\$10



# Economics of Production

## EcoWillow 2.0....

### Improved Base Case Scenario..

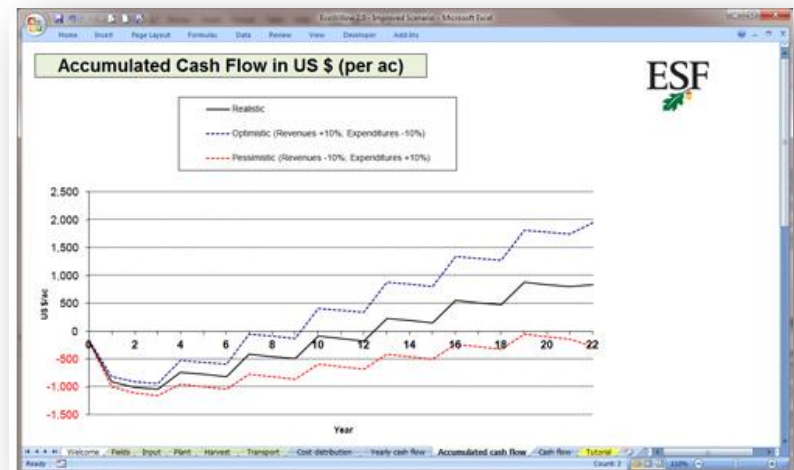
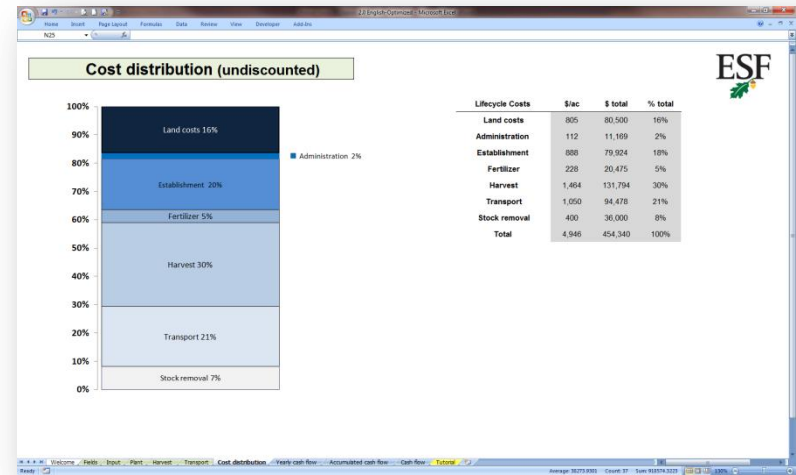
- IRR - 5%
- Payback - 13 years
- Production Costs - \$25/ton<sub>wet</sub>

### BCAP Improved Scenario...

- IRR - 20%
- Payback - 7 years
- Production Costs - \$20/ton<sub>wet</sub>

### 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)

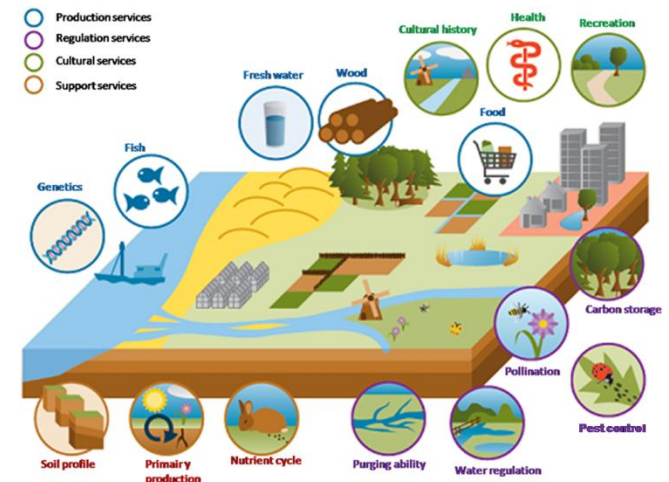
Vegetative land fill caps (evapotranspiration cover)

Waste water treatment (municipal and ag. wastes)

Vegetated buffers

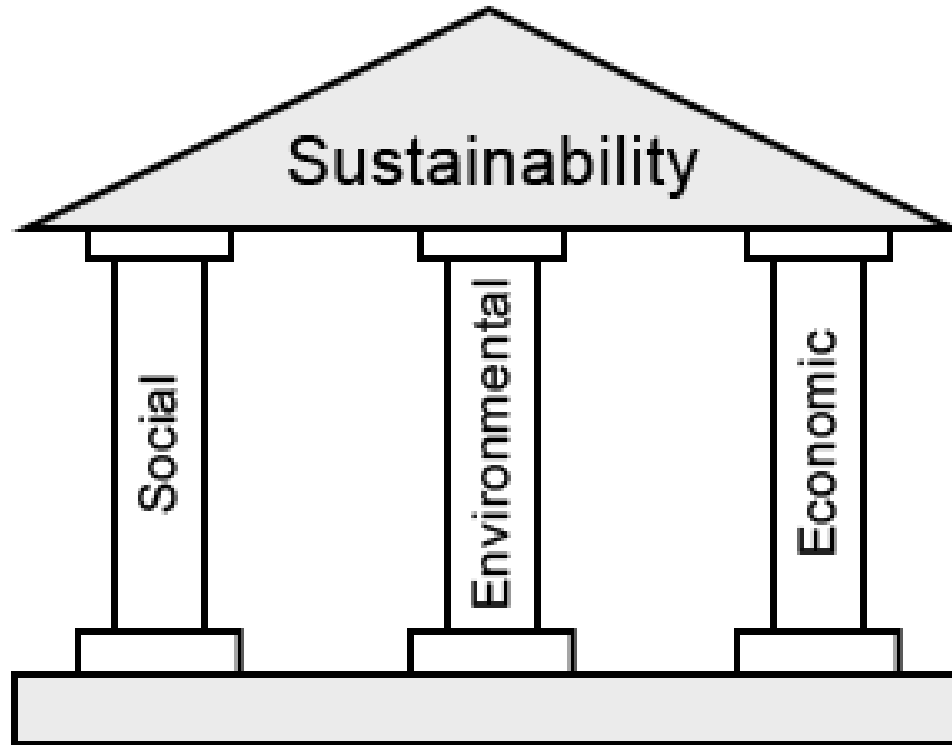
Other pollution controls

And more...



# Multiple Benefits

The best willow systems produce numerous benefits...



**Example...**

Solvay Settling Basins, Syracuse, NY.



# Solvay Settling Basins





# **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 18<sup>th</sup>

- One day conference at SUNY-ESF
- New Gateway Center
- Numerous speakers
- Tours of ESF biomass systems

### Wednesday November 19<sup>th</sup>

- Willow harvesting demonstration
- Location TBA

### Registration...

- \$50 including meals
- [www.esf.edu/willow](http://www.esf.edu/willow)



# Thanks for your attention!

# Questions?

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[www.esf.edu/willow](http://www.esf.edu/willow)