

The Potential of Woody Biomass for Bioenergy, Biofuels and Bioproducts



Timothy A. Volk, SUNY- ESF, Syracuse, NY
Biotechnology Symposium, May 21-22, 2012

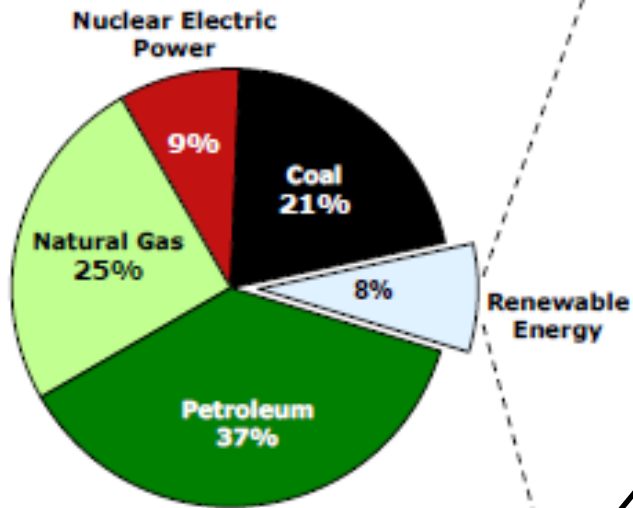


Outline

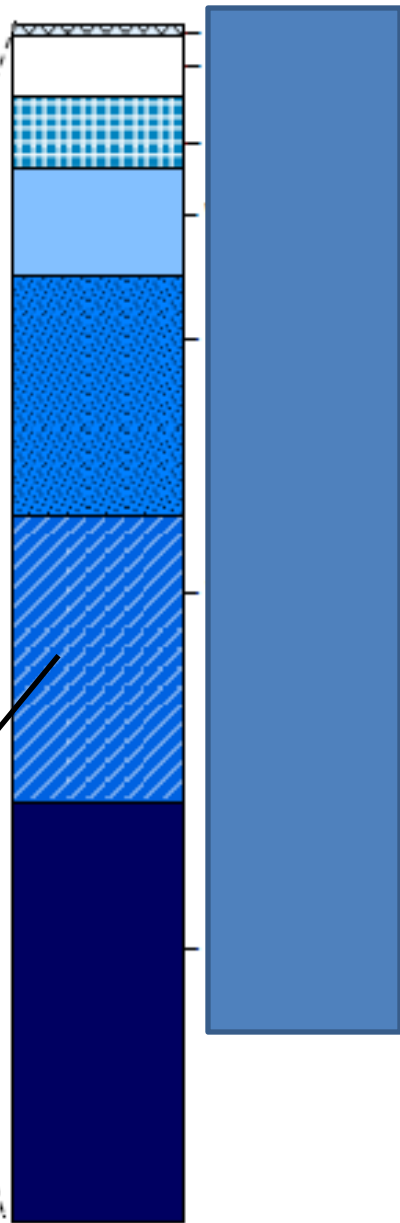
- Woody biomass and U.S. energy use
- Biomass resources in NY
- Willow biomass crop systems
- Making multiple products from woody biomass
- Additional benefits from willow biomass crop systems
- Summary

Renewable Energy as Share of Total Primary Energy Consumption, 2009

85% of U.S. energy comes from fossil fuels



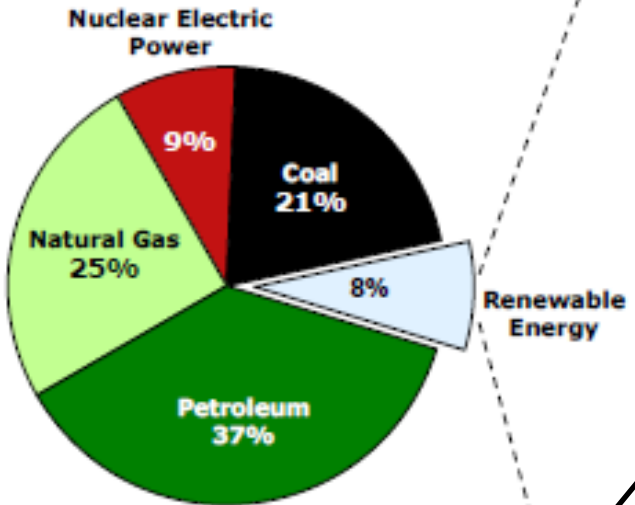
Wood supplies about 2% of all U.S. energy needs



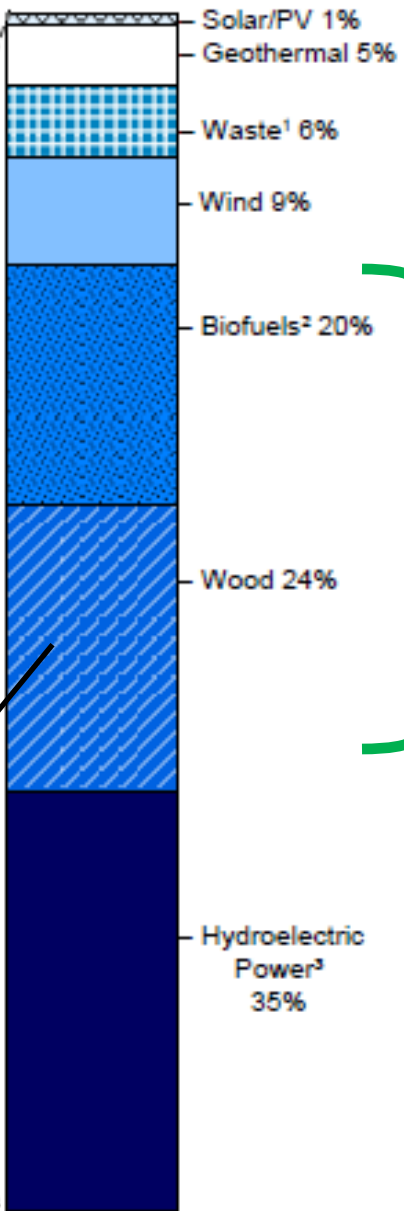
Biomass is the single largest source of renewable energy in the U.S.

Renewable Energy as Share of Total Primary Energy Consumption, 2009

85% of U.S. energy comes from fossil fuels



Wood supplies about 2% of all U.S. energy needs



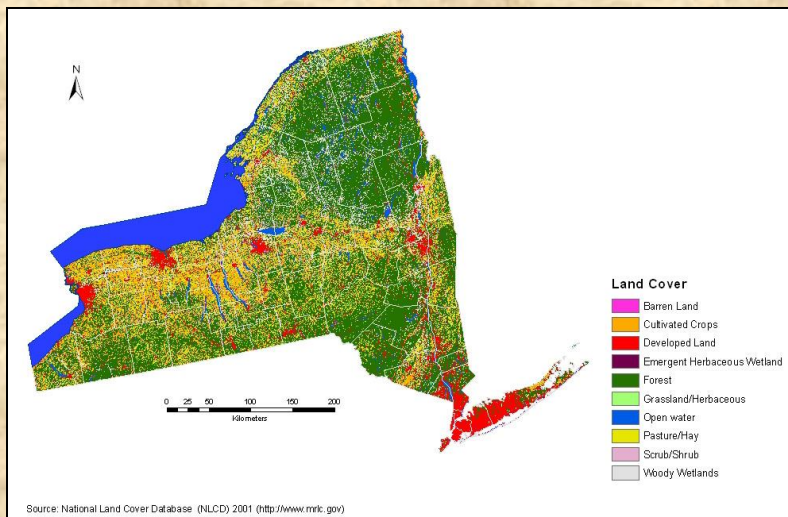
Biomass is the single largest source of renewable energy in the U.S.

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

Biomass Resources in NY

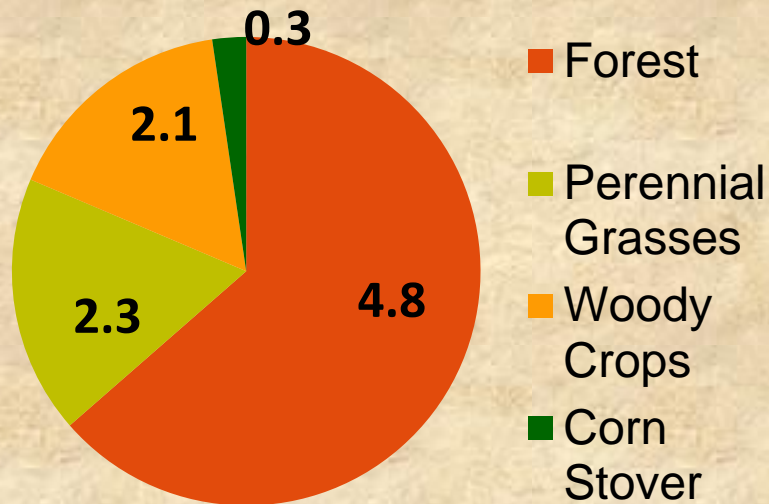
- NY has over 18.4 million acres of forest land
 - 15.8 million acres could be actively managed
 - Growing 3 times faster than it is being harvested
- Over 7.5 million acres of agricultural land in NY
- About 1.5 - 2.0 million acres are under utilized and could be used to grow perennial energy crops like willow or switchgrass
- Both forest and agricultural biomass produce environmental and rural development benefits in addition to bioenergy and/or bioproducts



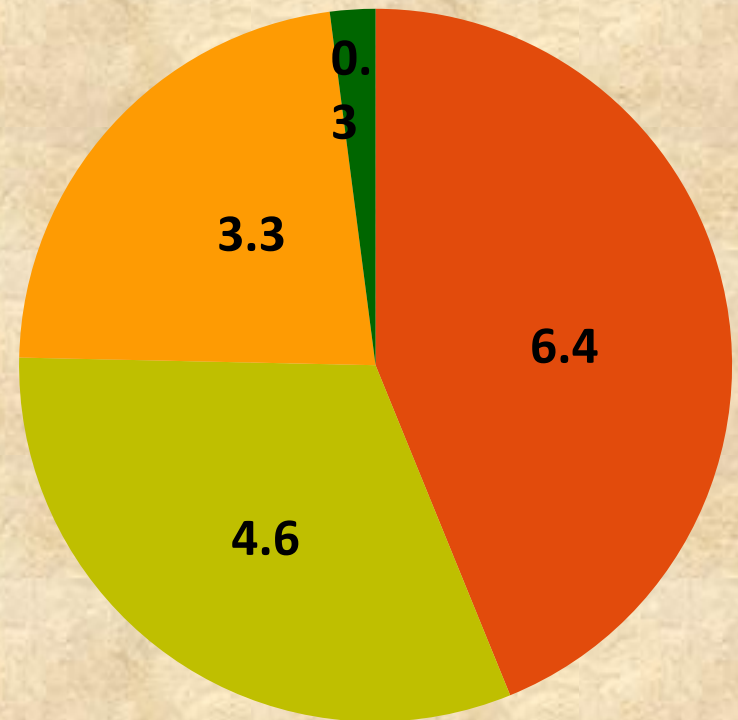
Land cover types in NY
(Woodbury et al. 2010)

NY Potential Biomass Production

Scenario #1
9.4 million odt/yr



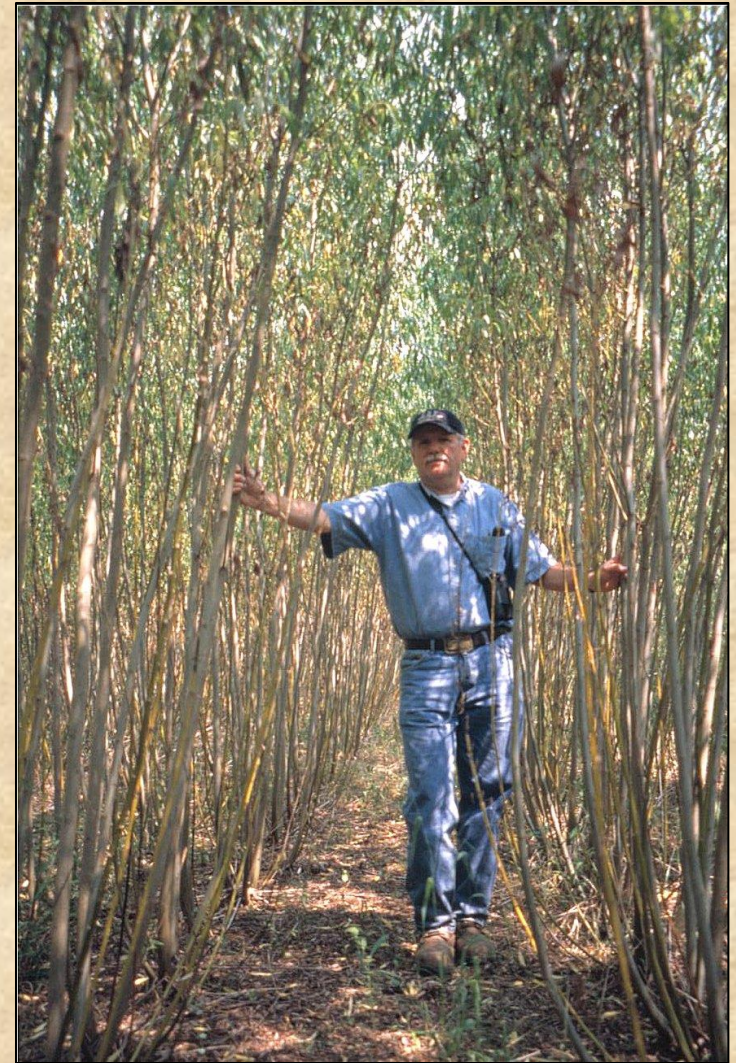
Scenario #2
14.6 million odt/yr



Potential biomass production (million odt/yr) in NY from different sources in two scenarios (Woodbury et al. 2010)

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)



Three year old willow biomass crops.



Willow Biomass Production Cycle

Site Preparation



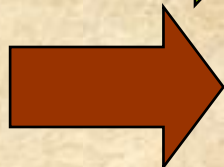
Planting



Harvesting



Coppice



First year growth



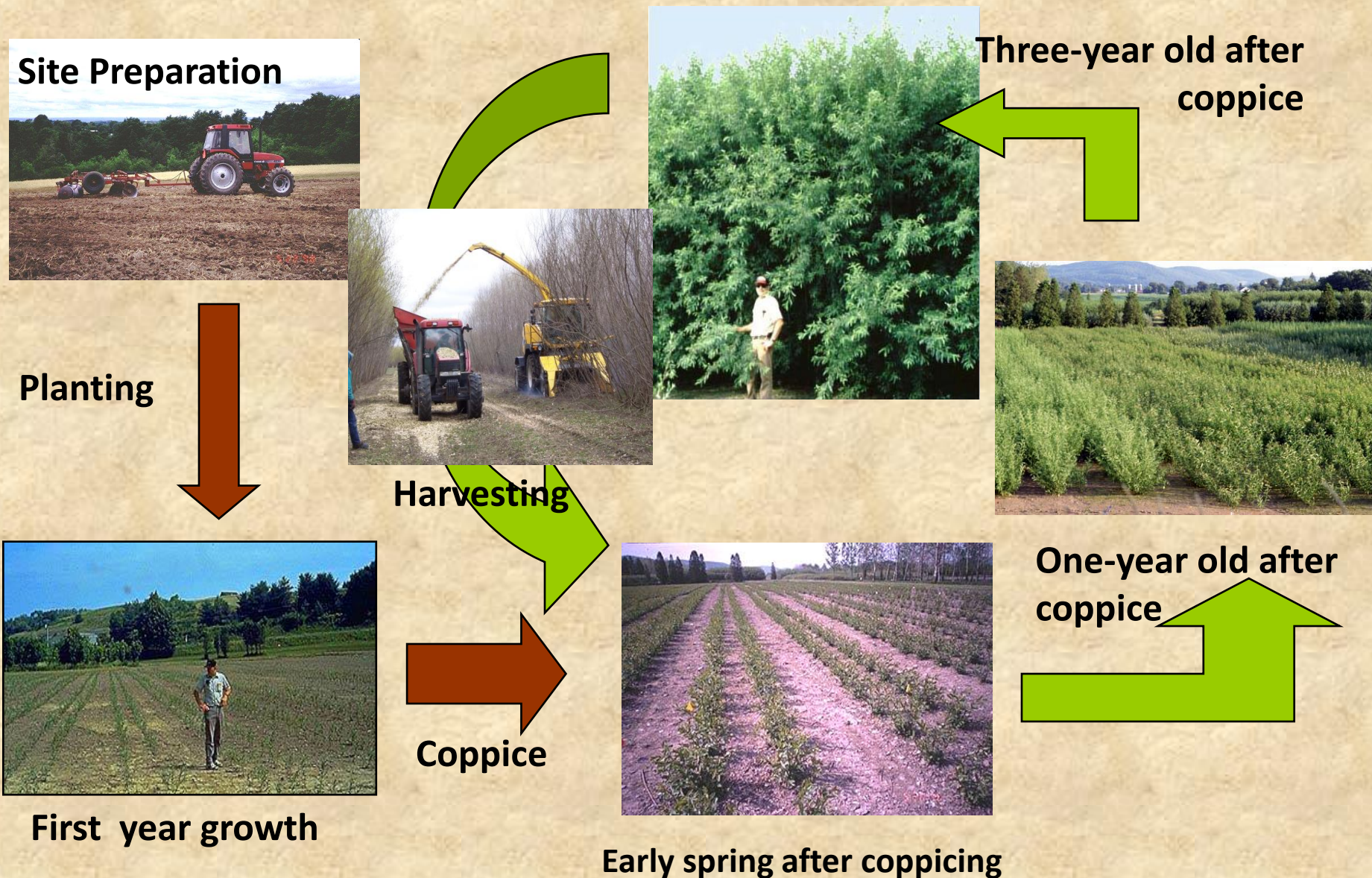
Early spring after coppicing



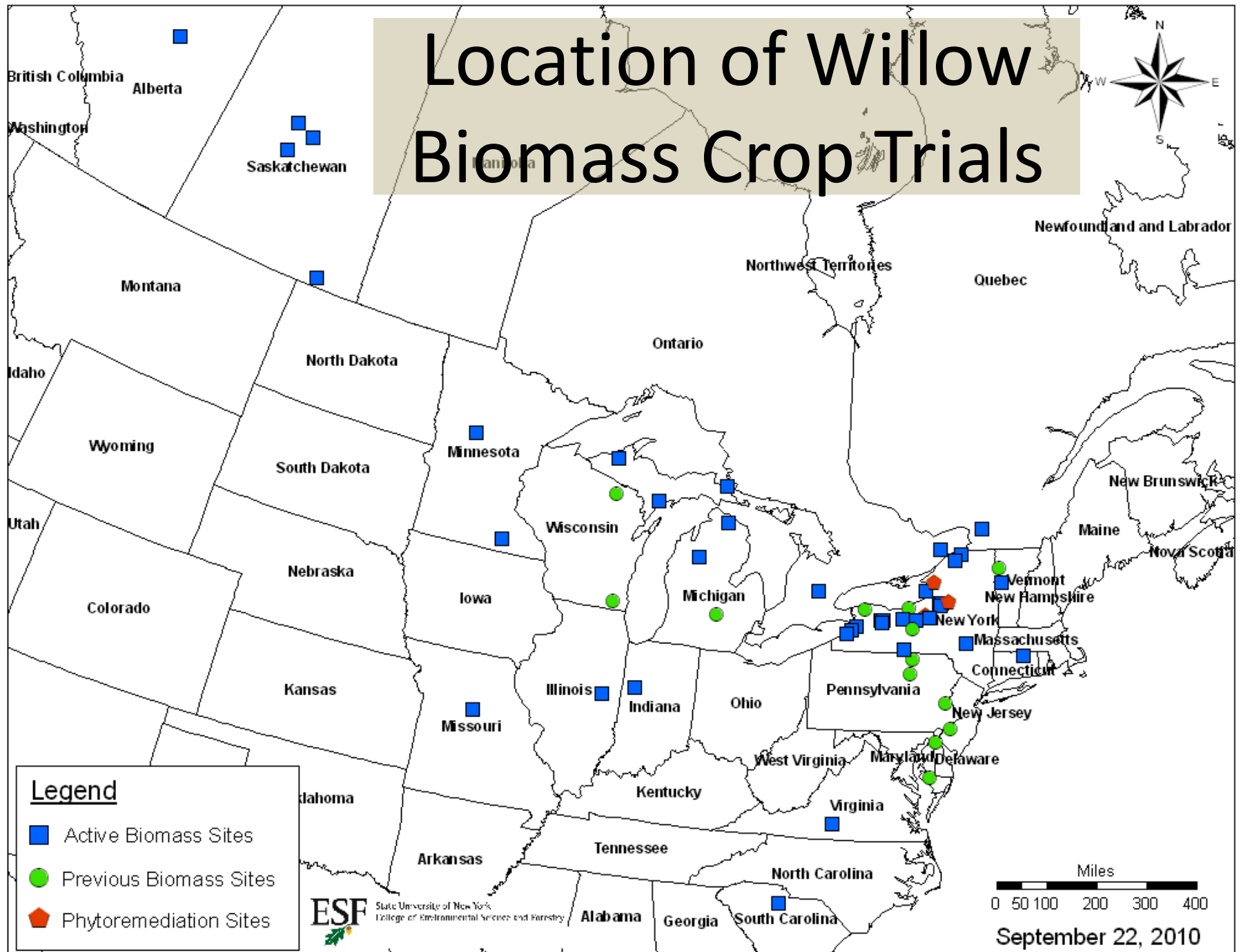
Three-year old after coppice



One-year old after coppice

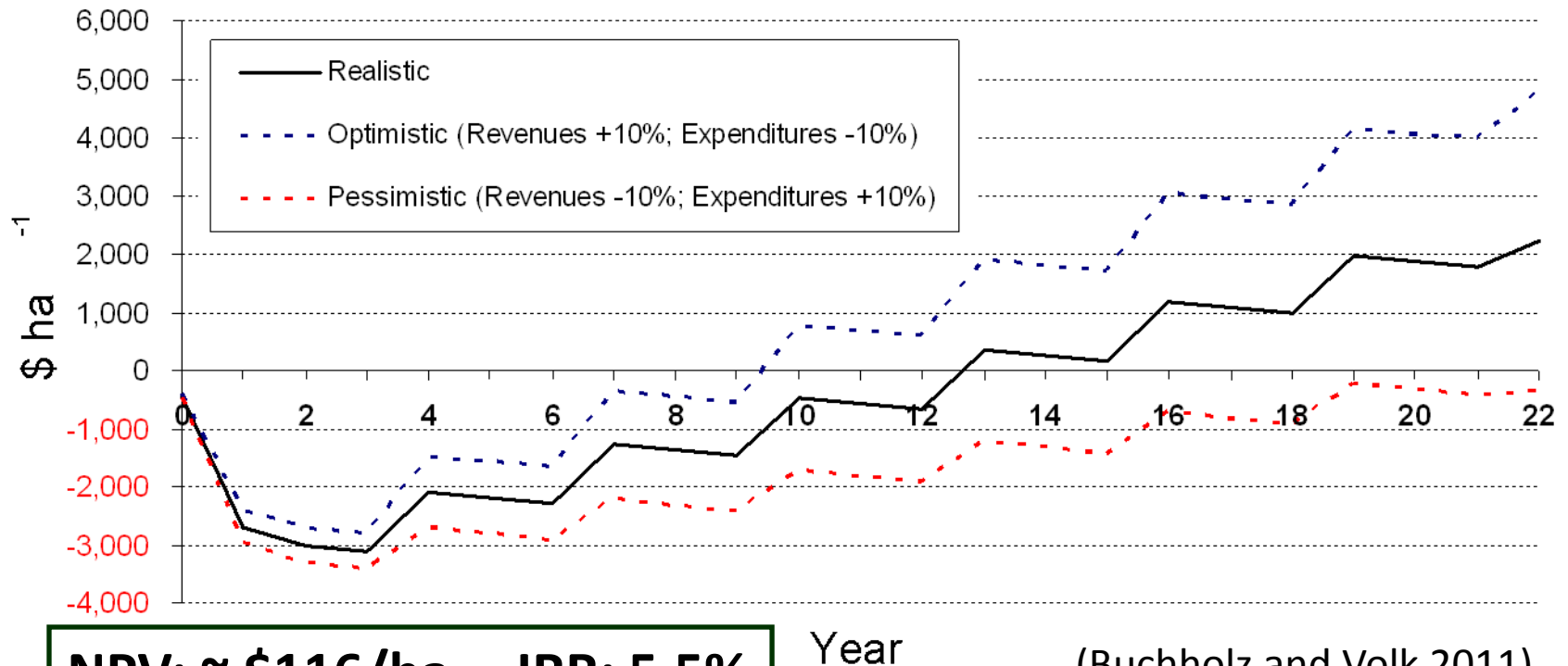


Location of Willow Biomass Crop Trials





Economics of Willow – Base Case



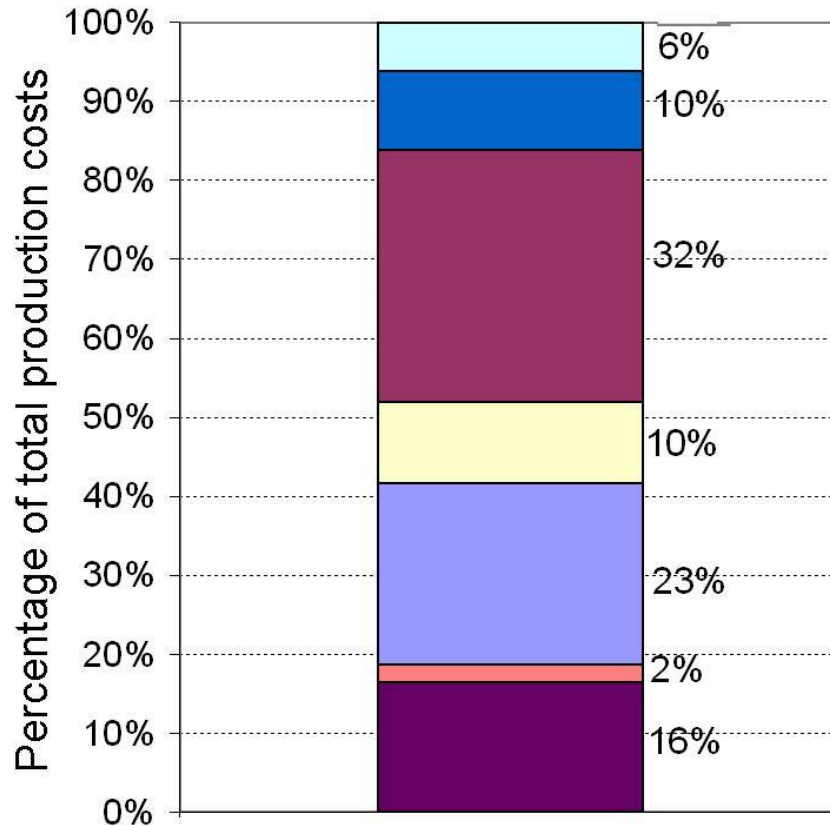
NPV: ~ \$116/ha IRR: 5.5%

Year

(Buchholz and Volk 2011)

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

Willow Production Cost Structure



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

Source: Buchholz and Volk 2010

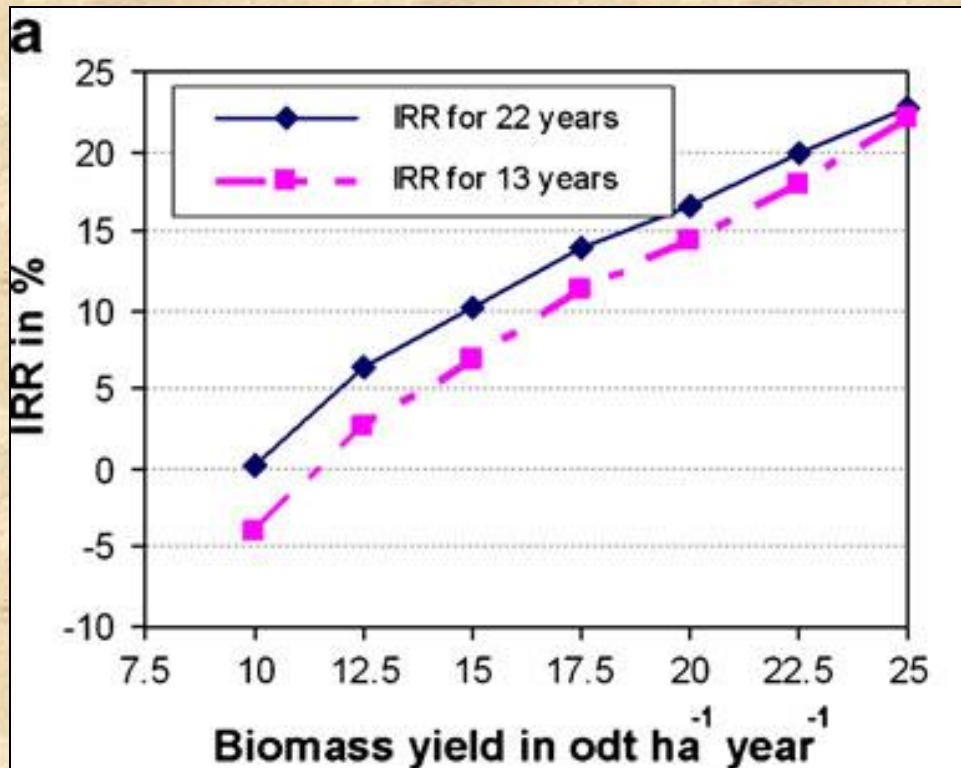
SRWC Harvester Development



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

- 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

Effect of Increased Yield



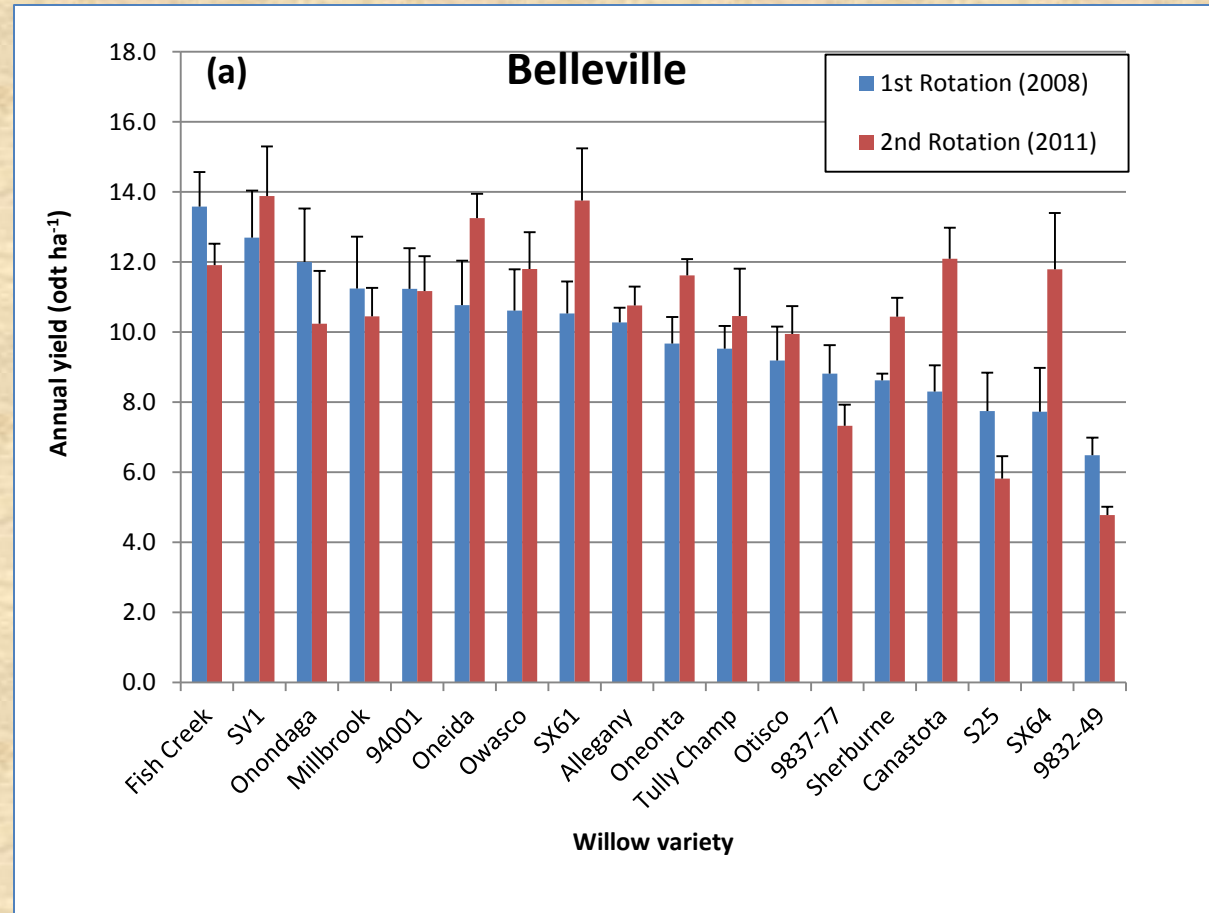
Effect yield on IRR of willow biomass crops (Buchholz and Volk 2010)

- With a base case yield of 12 odt ha⁻¹ yr⁻¹ 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



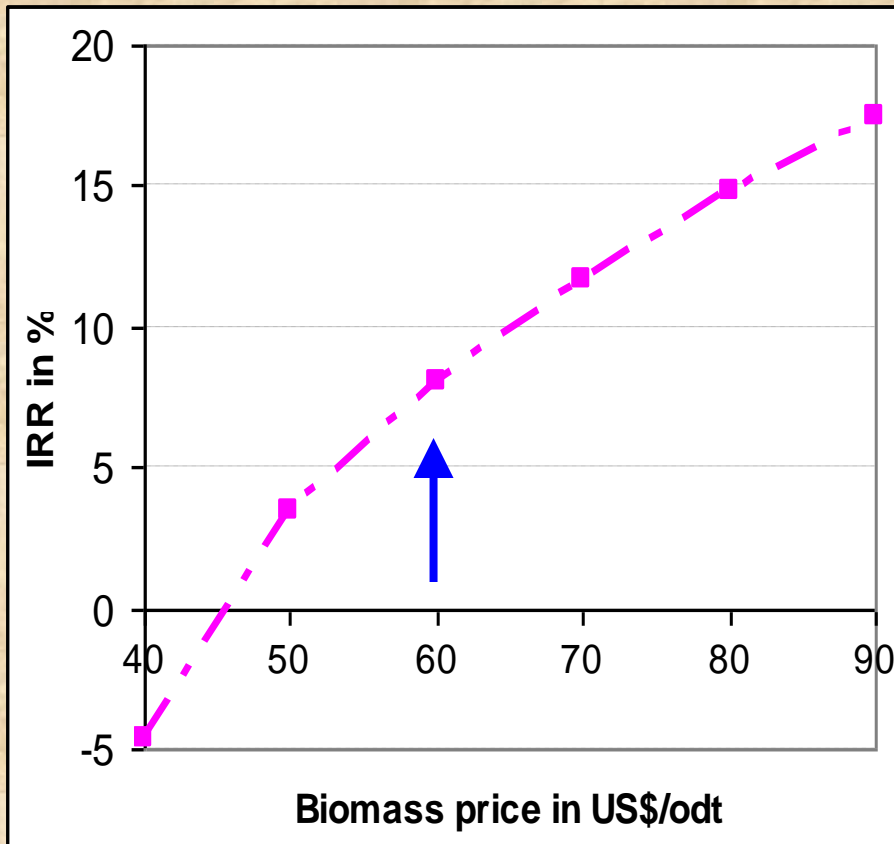
Willow Biomass Crops - Yields

- Second rotation yields of the best 6 varieties are greater than 11.5 odt/ha-yr (5.1 odt/acre-yr)
- New varieties have 15-30% greater yield than check varieties
- Breeding for yield, pest and disease resistance and form



First and second rotation yields of new willow varieties planted in upstate, NY (Volk et al. unpublished data)

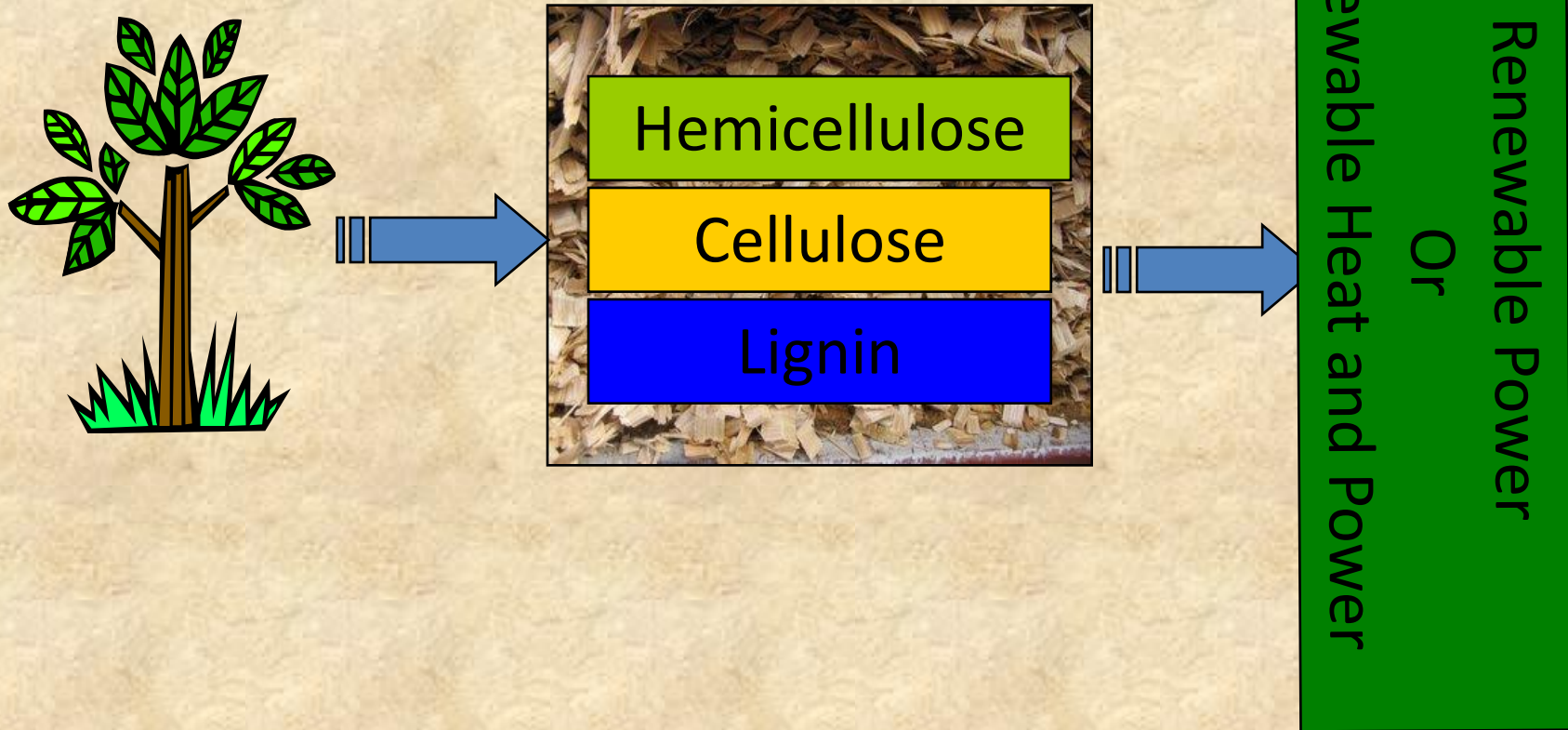
Price for Biomass



- 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

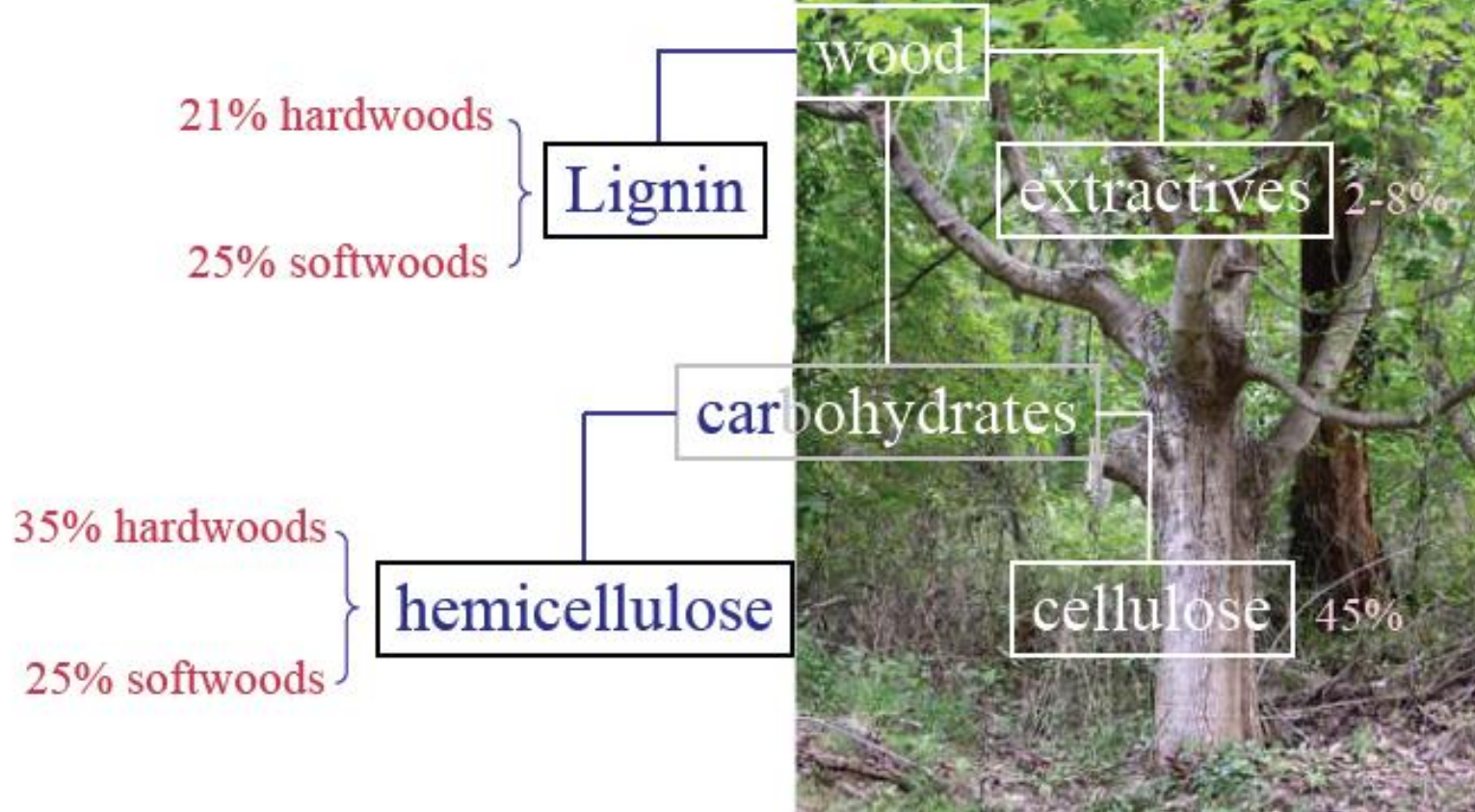
Effect of changes in the price for willow biomass on the crops IRR (Buchholz and Volk 2010)

Current Wood to Energy Facilities



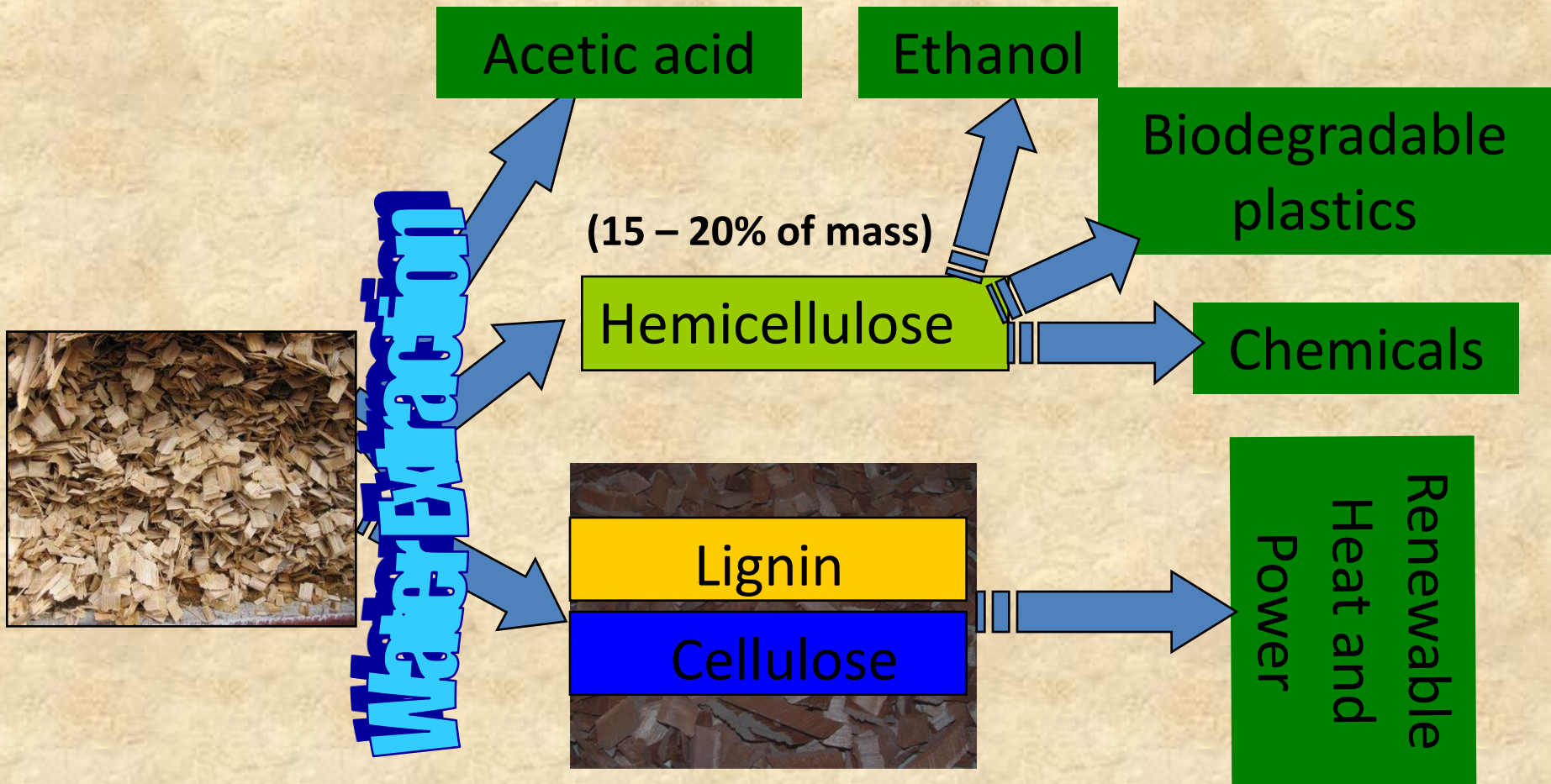
Woody Biomass

Chemical components of wood



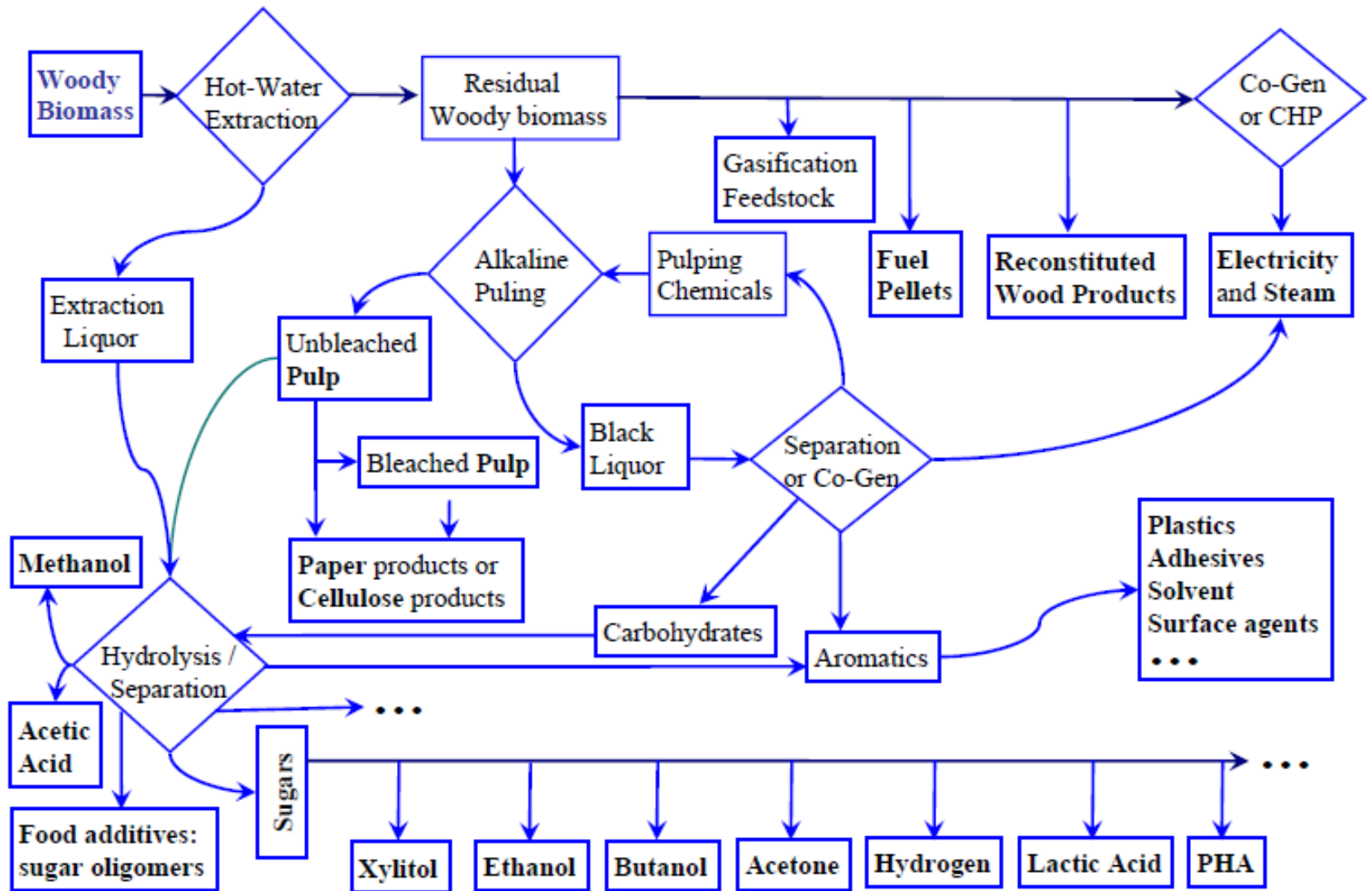
(Amidon et al. 2008)

Wood to Energy Biorefinery



Incremental deconstruction of wood to produce a range of higher value products from each ton of woody biomass.

Wood to Energy Biorefinery



Hot-Water Extraction





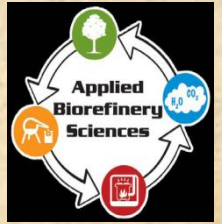
Raw Chips



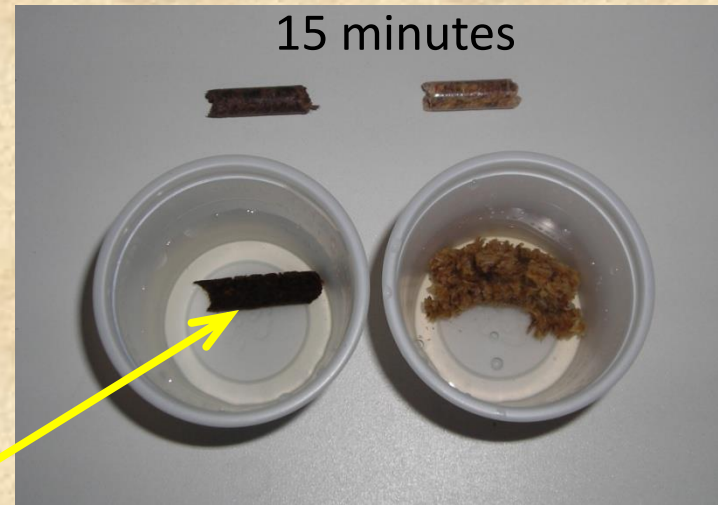
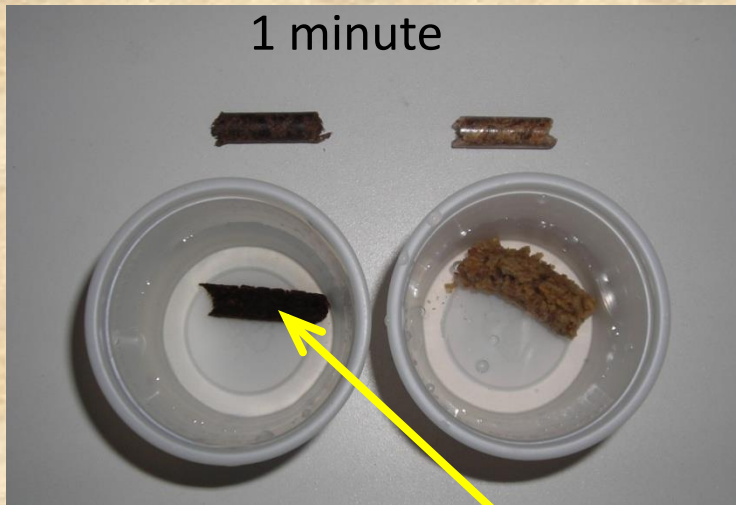
Extracted Chips

- 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 Wood



Submerge an extraction pellet & a conventional pellet in water



Extracted pellet still in tact

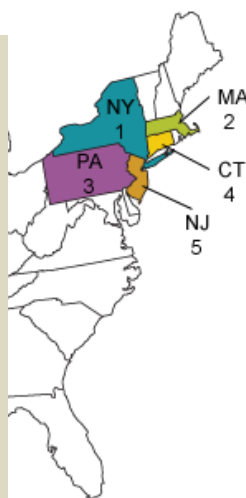


Use of Heating Oil

Top Five Heating Oil Consuming States in 2009

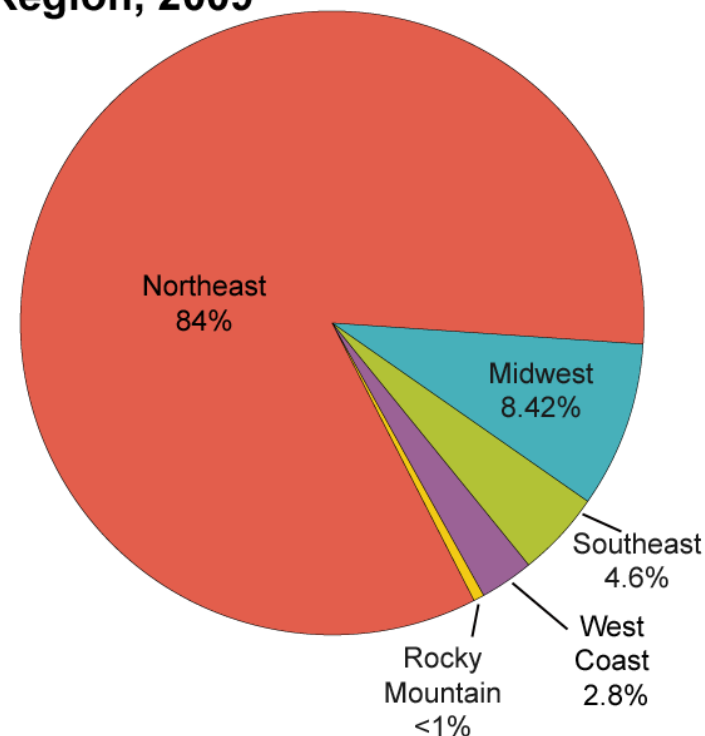
✓ 80% of the homes that use heating oil are in the Northeast

✓ Consumers in the Northeast use about 3.7 billion gallons of heating oil per year



Source: U.S. Energy Information Administration, *Fuel and Kerosene Sales 2009* (February 2011).

Sales of Residential Heating Oil by Region, 2009



Source: U.S. Energy Information Administration, *Fuel and Kerosene Sales 2009* (February 2011).

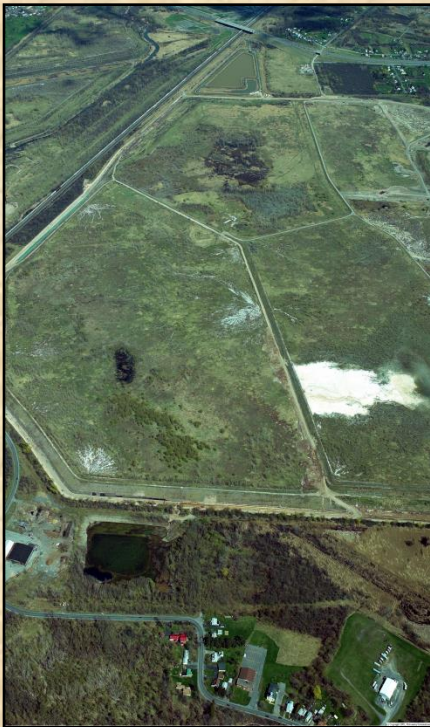
Current Willow Biomass Production System

- Decades of worldwide knowledge and experience
- Inherent characteristics of willow



Tailor biomass production system for specific objectives and site conditions

- use an adaptive management model



Alternative Covers



Living Willow
Snowfences



Willow Riparian
Buffers





Onondaga Lake and Upland Sites

Honeywell



Willow Variety Testing



More than 40 varieties studied for effective growth

Greenhouse Organic Nutrients



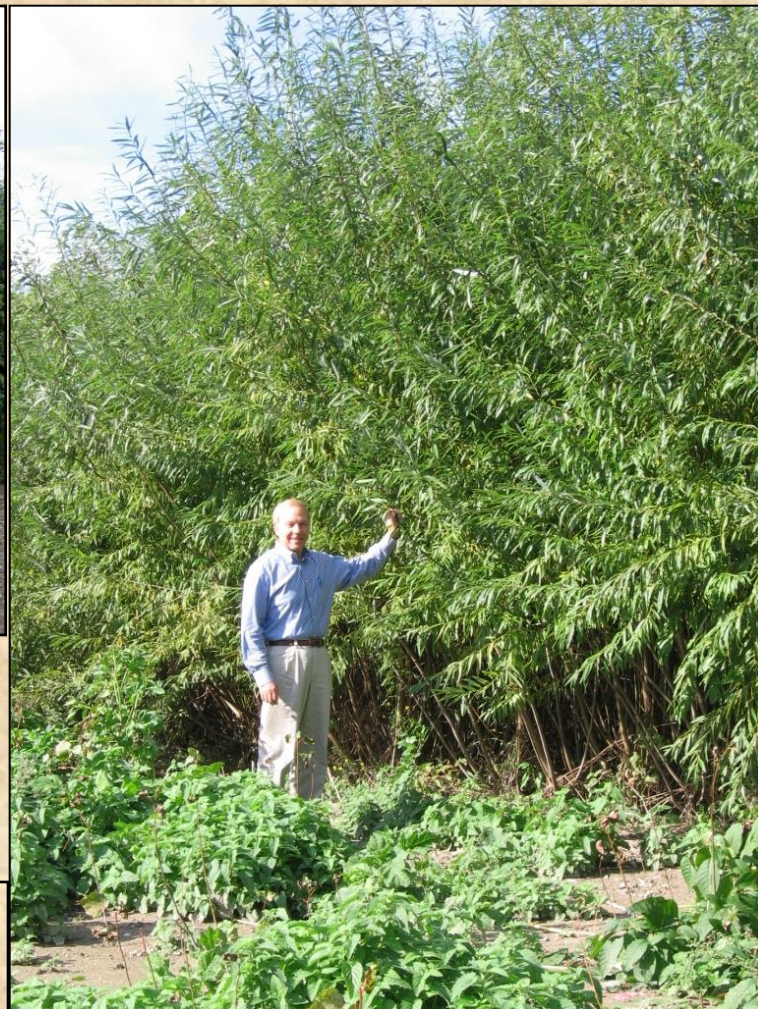
Five- and ten-week-old willows in organic nutrients (Farber 2006)

- Organic nutrients are added to soil and are essential for effective shrub willow growth
- Three locally available nutrients tested in SUNY-ESF greenhouse in 2004

Willow Trials on the Settling Basins



Three year old willow on Solvay setting basins



- Yield over first three years is comparable to willows grown on mineral agricultural soils in central NY.

Monitoring Willow Field Trials



- **Monitored willow survival, growth and development**
- **Measured sap flow and soil moisture characteristics**
 - Willows soak up water at a faster rate than that of a grass cover during entire growing season
- **Used data to calibrate water budget models**
 - Harvesting of willows is not necessary for this system to be effective



Two Year Old Willow



Late Fall



Full Scale Demonstration – 1st Year



Alternative Cap Expansion



- Expansion of alternative cover using willow underway
- 25 acres planted with willow in the spring or 2011
- Next 25 acres will be planted in the spring of 2012

Biomass

- Biomass is already an essential source of renewable energy
- Potential to expand the amount of biomass used and the range of products generated from biomass
- Use of biomass and generate multiple environmental and rural development benefits while providing renewable energy

Questions

