Impact of Willow Crop Management Activities on Willow Economics

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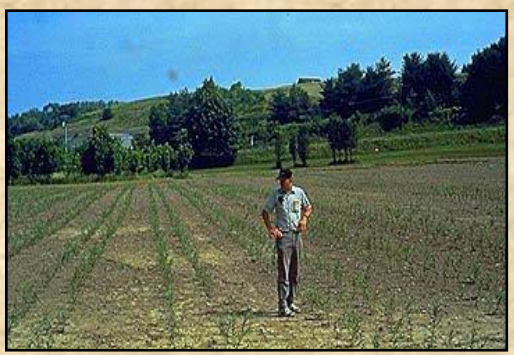
Outline

- Baseline willow production and economics
- USDA BCAP and NewBio programs
- Impact on economics of improvements/changes in
  - Harvesting
  - Cutting costs
  - Planting density
  - Yield improvements
  - Value of biomass

Willow Biomass Production Cycle

Planting



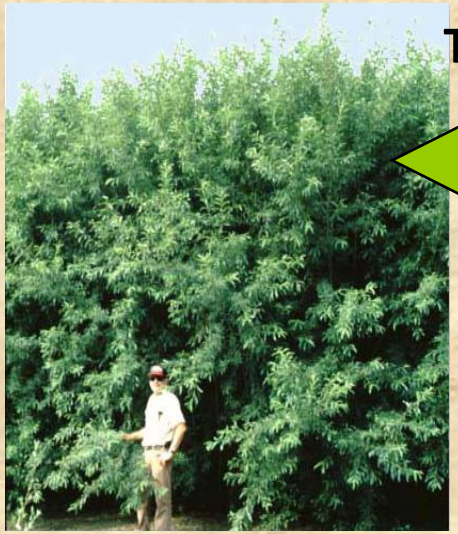
First year growth

Coppice

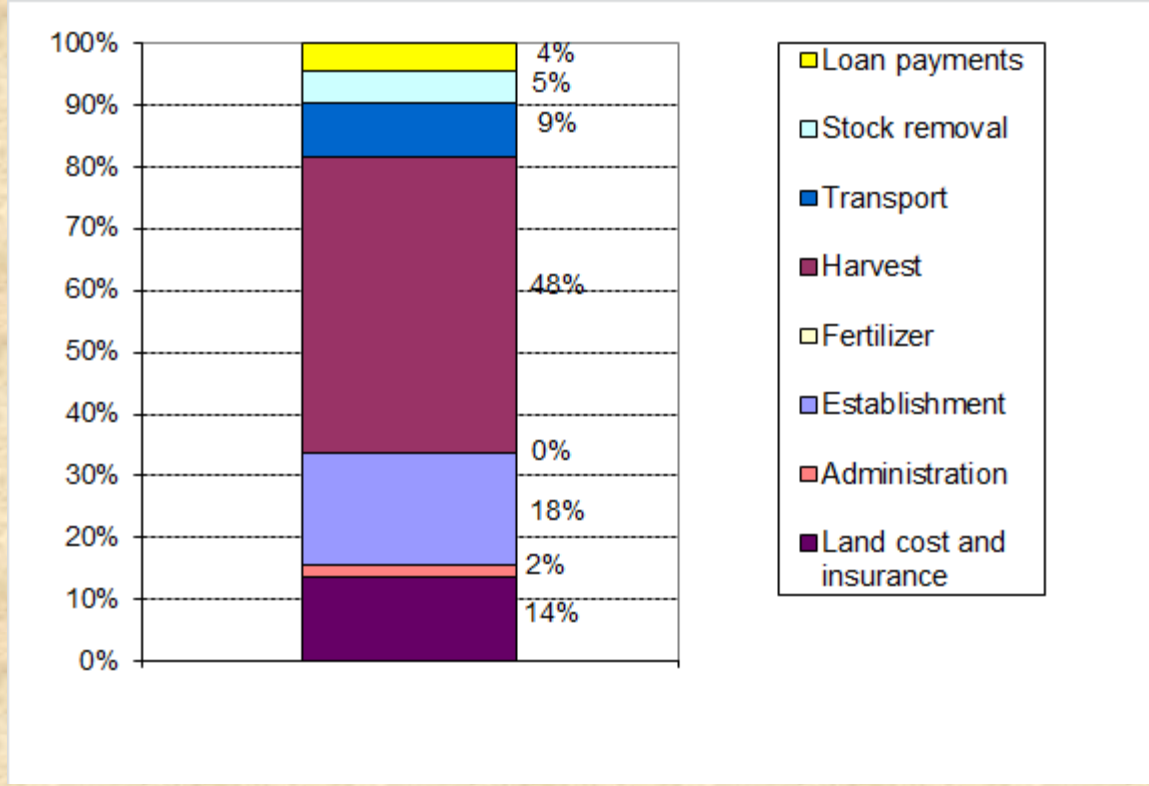
Early spring after coppicing

One-year old after coppice

Three-year old after coppice



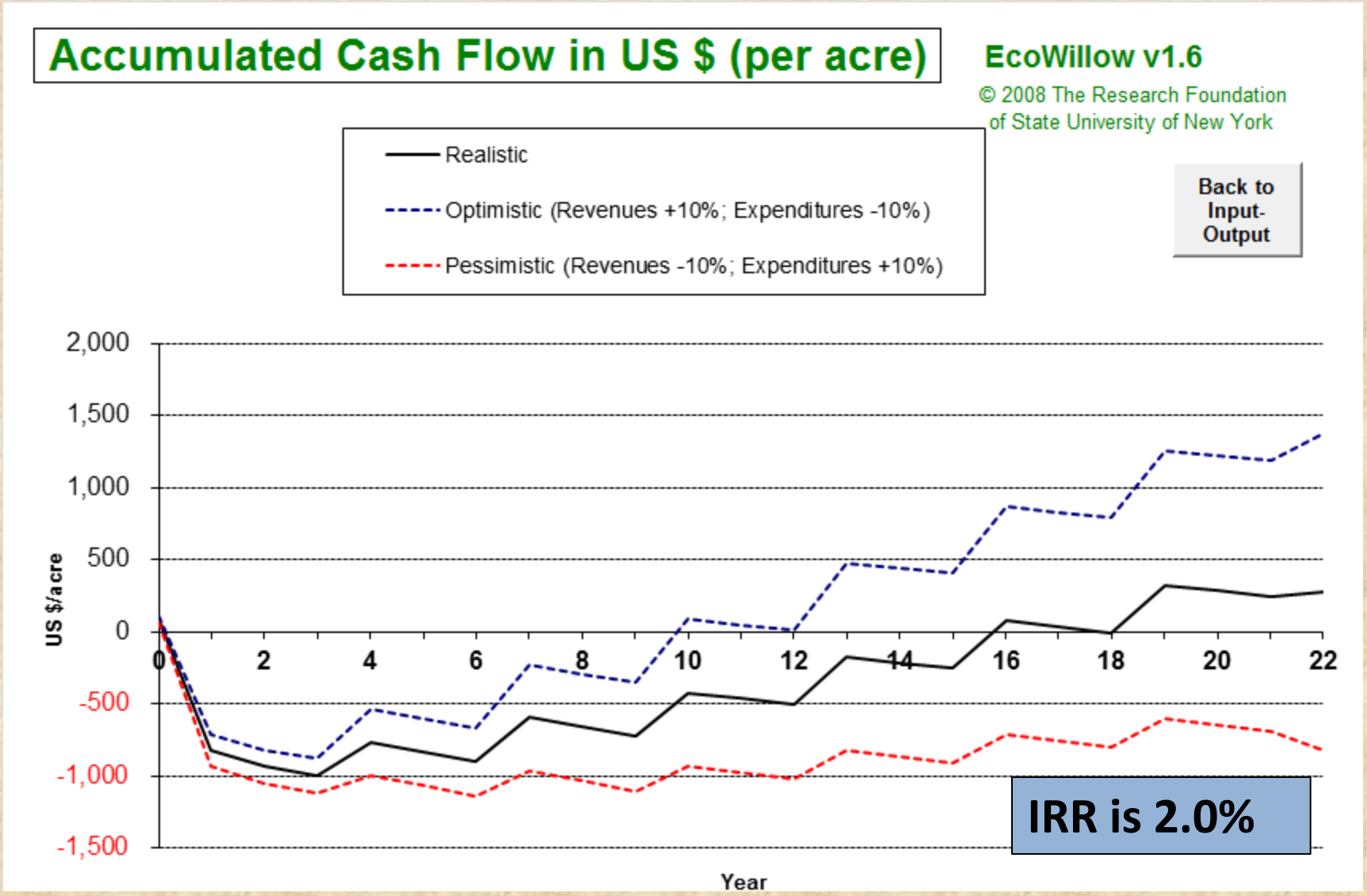
Baseline Condition



Distribution of costs for willow biomass crops over seven three year rotations

- 100 acre area
- Harvest speed – 1.9 mph
- 3 year harvest cycle
- Cutting cost $0.12/cutting
- Planting density – 5,800/acre
- 5 odt/ac-yr
- $60/odt delivered price

Baseline Condition



USDA BCAP - Willow Biomass Project

The BCAP project crops covers a nine county region in central and northern NY

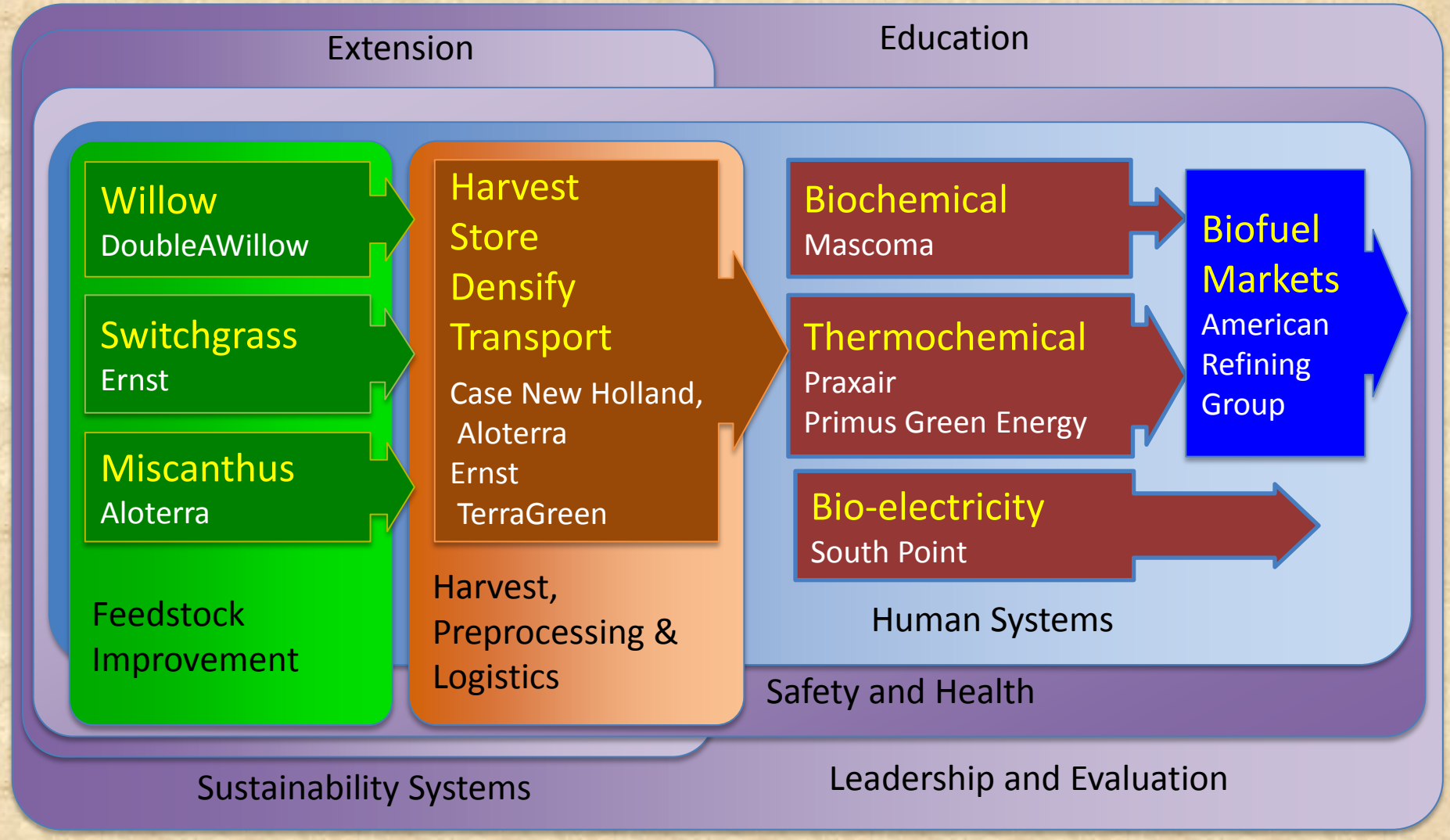
- USDA BCAP project for shrub willow in upstate NY
- 1,200 acres signed up in three month period
- ReEnergy Holdings will purchase all the willow biomass grown and using it in its Black River or Lyonsdale facilities
- Provides unique opportunity to
  - Collect data on crop management, willow growth,
  - determine the degree of variability at a commercial scale
  - generate improvements at a commercial scale

Willow BCAP Project

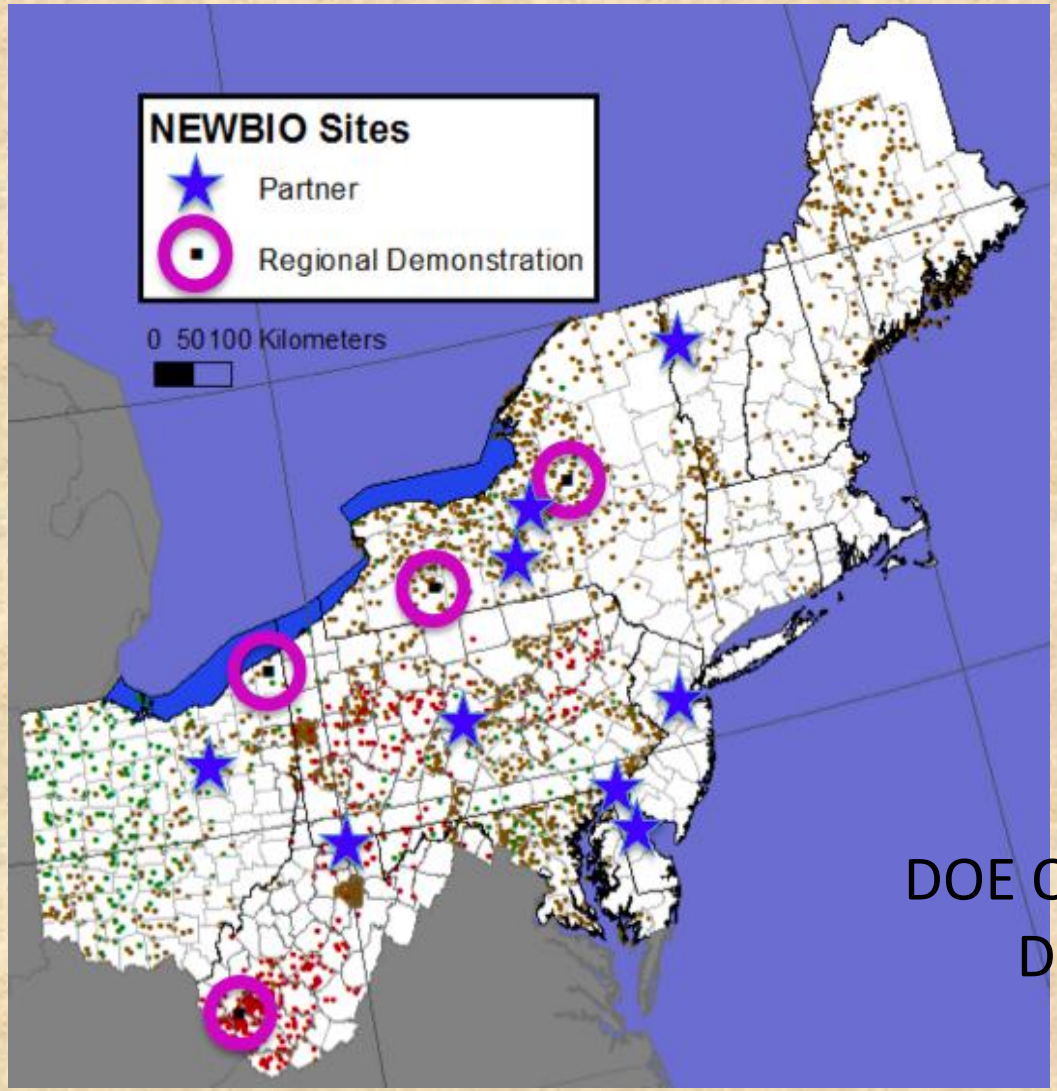
- Provides an establishment cost share payment of up to $741/acre
- Annual land payment based on soil rental rates
- No payment in year of harvest since value of crop exceeds payment value
- Average payment for three counties where land is enrolled is $50.67/acre-yr
- With establishment cost share and rental payment the IRR is 21.1%

NEWBio:

Northeast Woody/Warm-season Biomass Consortium



NewBio:University and Federal Partners



Penn State University
Cornell University
SUNY ESF
West Virginia University
Delaware State University
Ohio State University
Rutgers University
Drexel University
USDA ARS ERRC
DOE Oak Ridge National Laboratory
DOE Idaho National Laboratory

Changes in Harvesting Costs

Harvesting willow biomass crops with a New Holland forage harvester and specially designed header

- Largest single cost
  - At harvester speed of 1.9 mph cost is about $27.7/odt
- Data to date based on small plot harvesting operations (<10 ha)
- Collect data from large scale harvesting operations this fall and winter (> 160 ha)
  - Harvester productivity
  - Fuel use
  - Commercial scale yields

Changes in Harvesting Costs

Portion of the almost 300 acres of willow planned for harvest this fall

- Harvesting rates of 3.0 mph have been measured in willow
  - harvest cost is $18.8/odt and IRR is 6.6%
- If near term improvement is only 2.6 mph then cost is $21.5/odt and IRR is 5.4%

Rotation Length

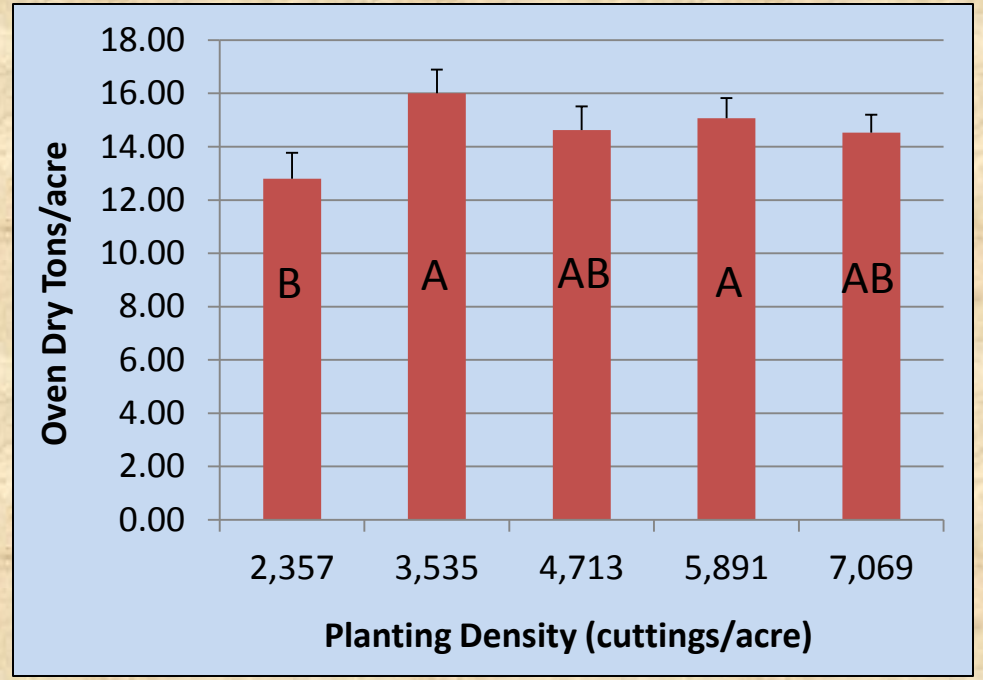
- Potential to shift from three to four year rotation
- Reduces the number of harvests and spreads the cost of each harvest operation over more tons
- Makes cash flow from system more sporadic
- Improves the internal rate of return from 2.0% to 5.0%

Planting Stock Costs

Harvesting one year old willow stems for planting stock production

- Establishment is the second largest cost category
- Cuttings account for over 90% of planting costs
- Commercial nursery (DoubleAWillow) has over 140 acres of willow and years of experience
- Improvements in harvesting, processing and handling could reduce costs
- Reducing cutting cost by 25% would lower planting cost
- Increase overall IRR to 3.1%

Changes in Planting Density



Production at the end of the first rotation across five planting densities for four clones in Tully, NY

- Density trials in NY and MN with four varieties and five planting densities
- No density x variety interaction ($p = 0.67$)
- Both density ($p = 0.02$) and variety ($p < 0.001$) are significant
- First rotation results suggest that planting density could be reduced from 5,800 to about 3,600 without a loss in yield

Reducing Planting Costs

- Reducing planting density would lower planting costs by about 33%
- Internal rate of return would increase to 4.1%
- Combining lower planting stock costs and lower planting densities would lower planting stock costs by 46%
- IRR would increase to 5.3% with reductions in planting stock costs and a lower planting density
- Other potential gains with expansion related to lower cost of producing planters and efficiency gains in planting operations

Improvements in Yield

- Two different factors involved:
  - Changes in production over multiple rotations
    - Based on trials planted in late 1990s
  - Improvements in production with new willow varieties
    - Based on 9 trials across a range of sites that were planted starting in 2005
- Combine the two sets of data to provide yield estimates for willow biomass crops

Changes in Production Over Multiple Rotations

	1st to 2nd Rotation	1st to 4th Rotation
Individual varieties	25 increased 5 decreased	17 increased 13 decreased
Range of change	-30% to 55%	-65% to 99%
Mean change for all varieties	19.4%	13.6%
Mean change top 10 varieties	23.0%	60.0%
Change for commercial varieties (SV1, SX61, SX64, SX67)	21.6%	30.8%

(Volk et al. 2011)

Importance of Improved Varieties and Long Term Data

	Mean Yield from First Rotation in Nine New Yield Trials	Mean Yield Over 7 Rotations Only Using Increase from 1st – 2nd Rotations	Mean Yield Over 7 Rotations with Increase from 1st – 2nd and 1st – 4th Rotations
	(odt ac^{-1} yr^{-1})		
Top variety	7.6	8.3	9.5
Top 3 varieties	5.2	6.3	6.5
Top 5 varieties	5.0	6.0	6.2
Top 3 New varieties	5.1	6.1	6.4

(Volk et al. 2011)

- Increase yields by 26% (6.3 odt/ac-yr) increases the IRR to 8.7%
- Increase yields by 13% (5.7 odt/ac-yr) increases the IRR to 5.8%

Increasing Willow Biomass Value

- Produce multiple products from each ton and/or improve the quality of the biomass
- Increase value to $80/odt raises IRR to 10.7%
- Increase value to $70/odt increases IRR to 7.0

ABS Process™

CleanTech disassembly of woody biomass to capture value not currently realized

Extracted Woody Biomass

Water-based Extract Solution

Pathway A

Hot Water Extraction™

Pathway B

Generating two product streams instead of just one

Wood Uses After *Hot Water Extraction™*

Improved → ***Hydro-Torrefied*™ fuel pellets**

- Lowers ash content of willow pellets from 1.4% to 0.7%
- Increased energy content by 5% from 7,979 btu/lb to 8,349 btu/lb
- Hyrdo-torrified pellets do not absorb water

HWE Pellets **Hardwood Pellets**

After 1 minute

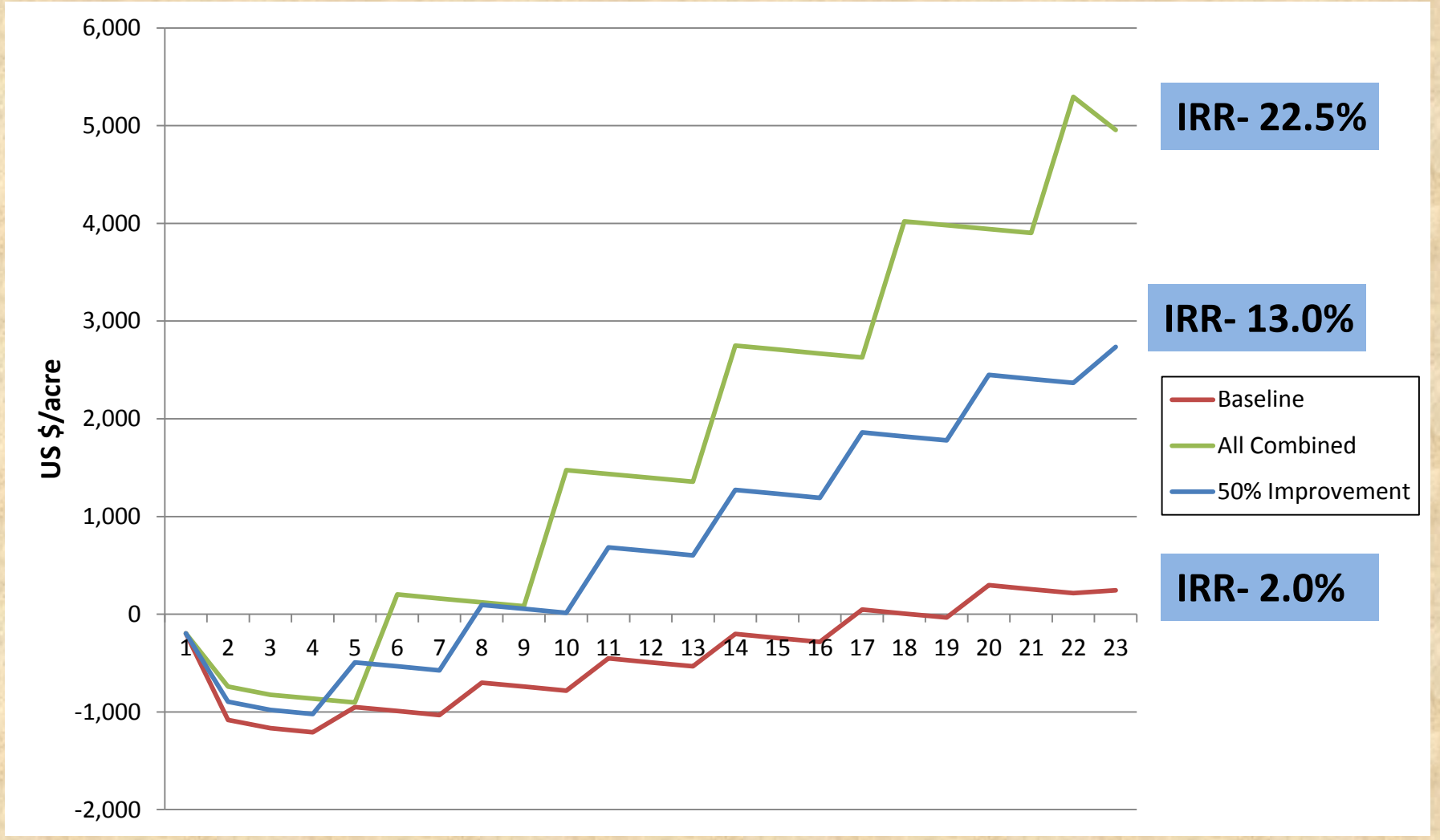
HWE Pellets **Hardwood Pellets**

After 15 minutes

Impact of Combined Changes

	Individual Factors (IRR -%)			Combined Factors (IRR - %)	
	Base-line	100% Improvement	50% Improvement	100% Improvement	50% Improvement
Harvesting Rate	2.0	6.6	5.4	6.6	5.4
Harvest Cycle	2.0	5.0	-	7.6	-
Cutting Cost	2.0	3.1	2.6	8.3	5.8
Planting Density	2.0	4.1	2.8	11.0	6.4
Yield Improvements	2.0	8.7	5.8	15.4	9.3
Value of Biomass	2.0	10.7	7.0	22.5	13.0

Impact of Combined Changes



Conclusions

- Currently returns from willow biomass crops are marginal
- Implementation of USDA BCAP project for willow in northern NY will provide opportunity for benefits from commercial scale operations
- Other crop management R&D and breeding work is producing results that will improve returns
  - Need to work to translate these benefits into gains at commercial scale
- Generating more value from each ton of biomass will increase returns

Acknowledgements

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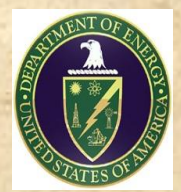

Questions