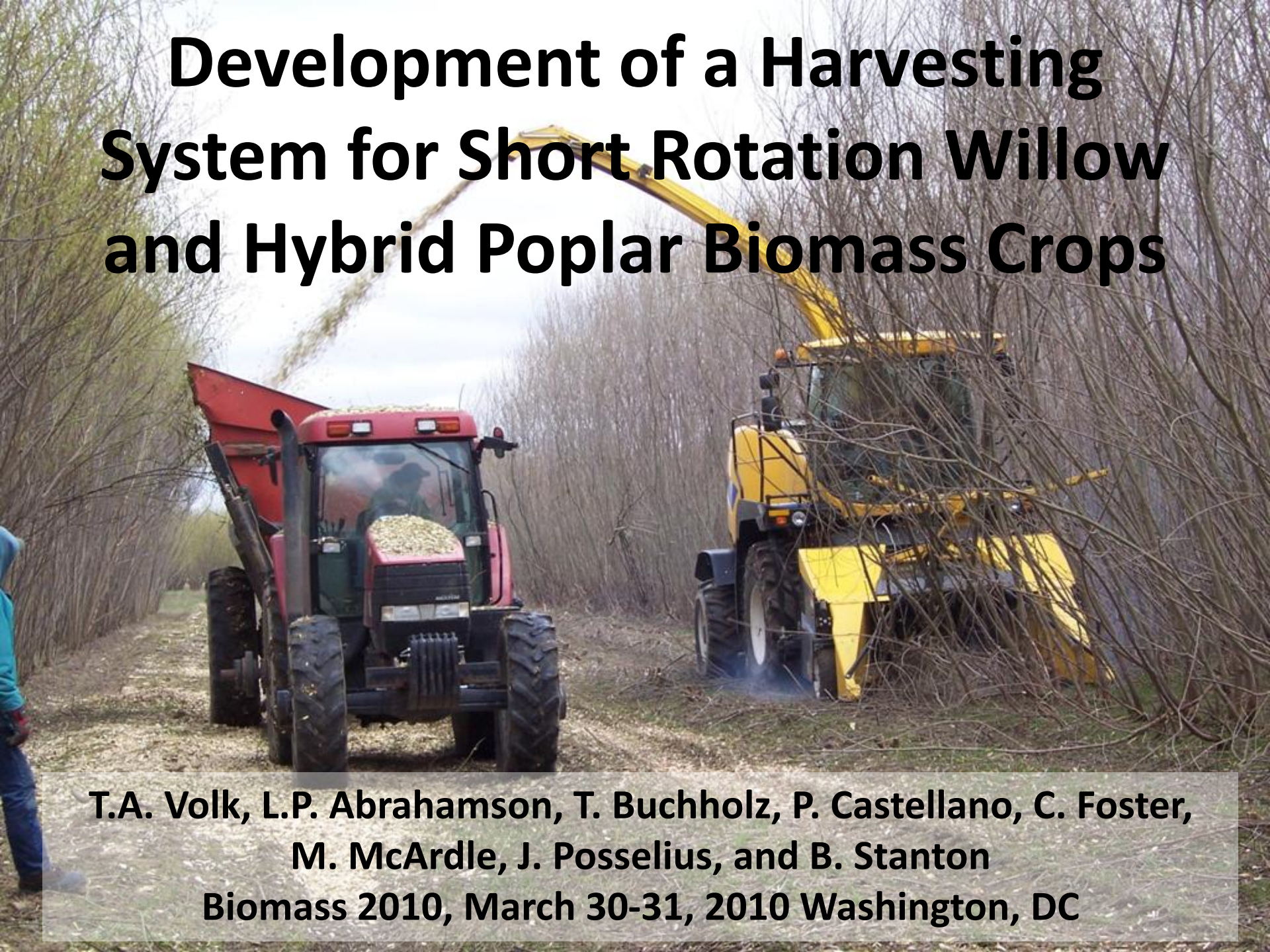
Development of a Harvesting System for Short Rotation Willow and Hybrid Poplar Biomass Crops



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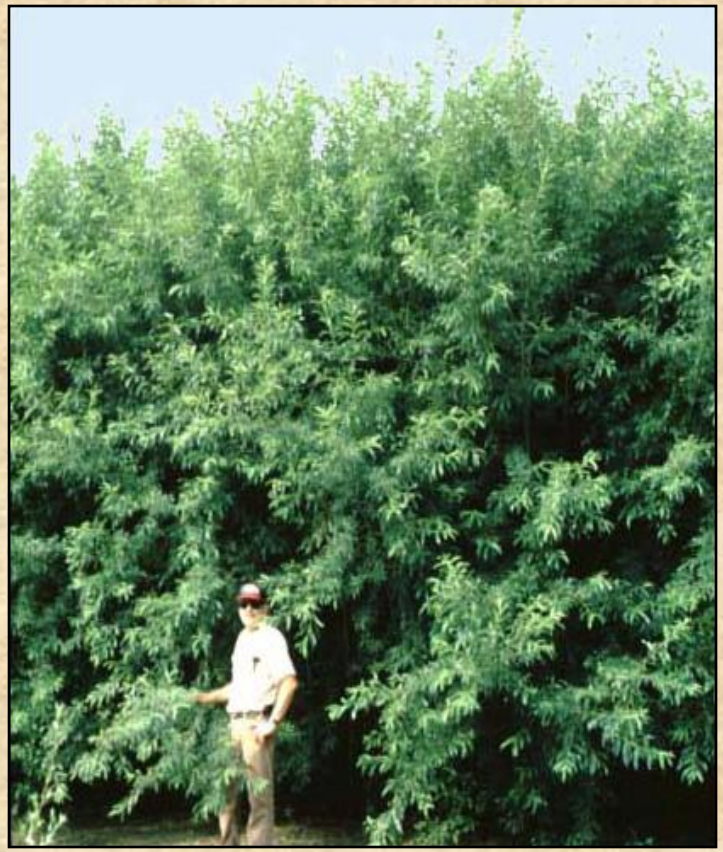
Biomass 2010, March 30-31, 2010 Washington, DC

Project Collaborators

Overview

- Willow biomass crop production systems
- Importance of harvesting systems
  - Economics
  - Energy inputs
- Development of willow and hybrid poplar biomass crop harvesting systems in North America
- Developing higher value products from woody biomass
- Future plans

Why Willow?



Three-year old willow in Tully, NY

- High biomass production potential
- Easily established with unrooted cuttings
- Resprouts vigorously after each harvest
- Wide range of genetic variability
- Limited insect and pest problems
- Over 40,000 acres of commercial plantings in Europe
- Over 1,000 acres planted in NY, MI already with more planned in 2010 in other states
  - 1-2 acre active yield trials in 10 States and three provinces in Canada

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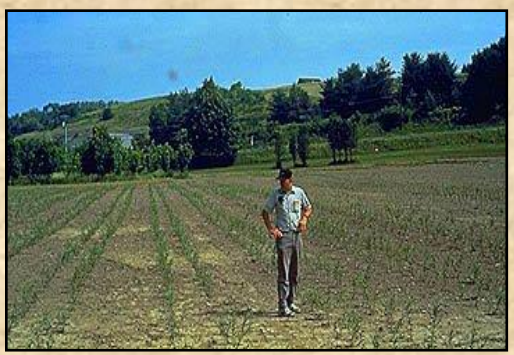
Willow Biomass Production Cycle

Planting



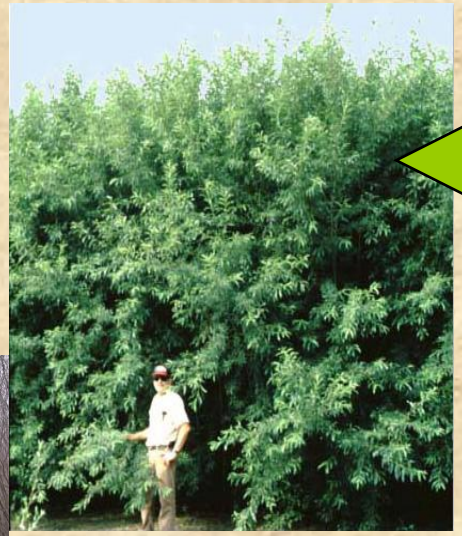
First year growth

Coppice

Early spring after coppicing

One-year old after coppice

Three-year old after coppice



Willow Cash Flow Model

Welcome to EcoWillow v1.3 (Beta)

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

SUNY-ESF
Improve Your World

Photo: Thomas Buchholz

Photo: Timothy Volk

Photo: Timothy Volk

Photo: Lawrence Smart

Project Name	
Location	
Acres (min. 20)	20

Begin

Tutorial

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

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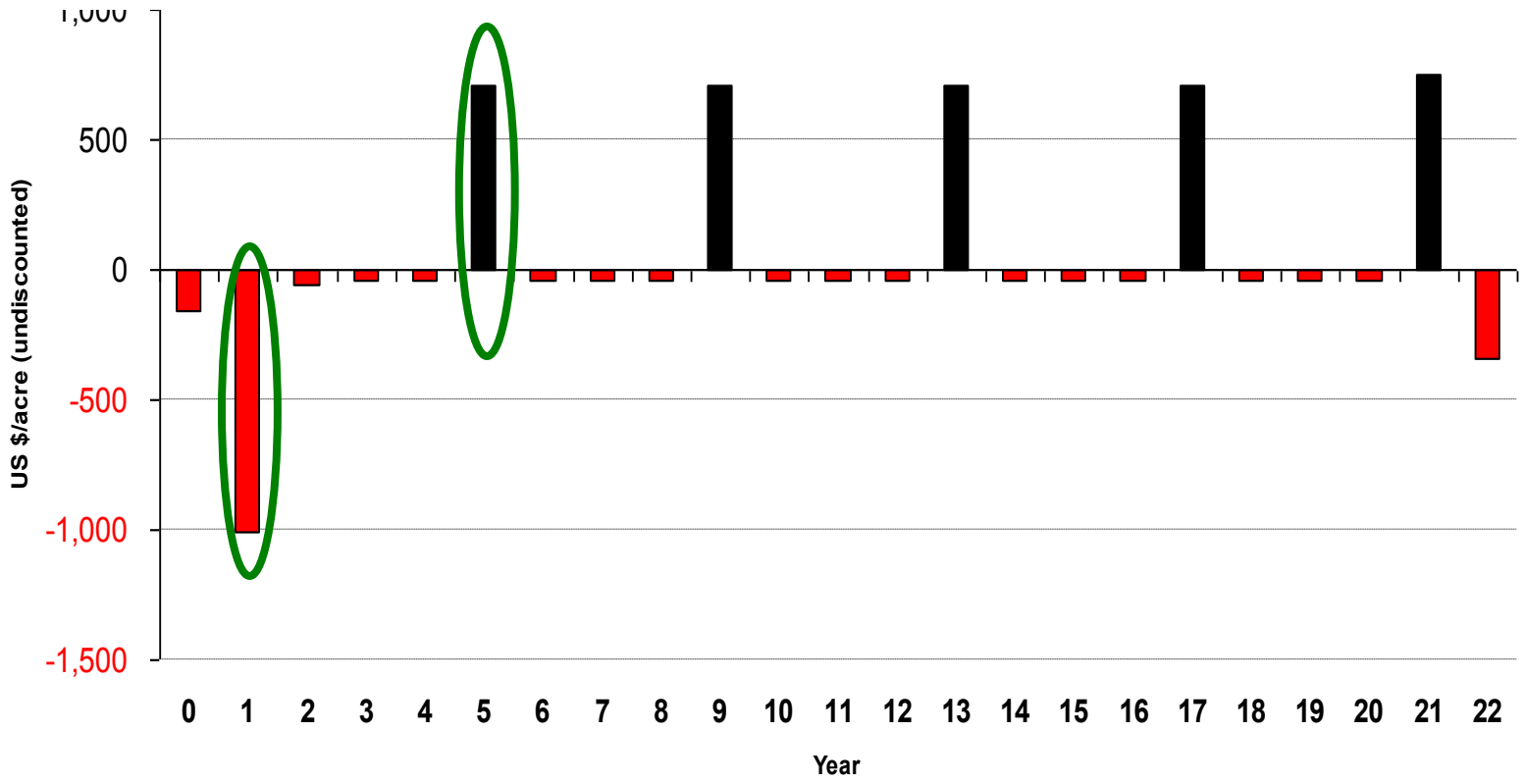
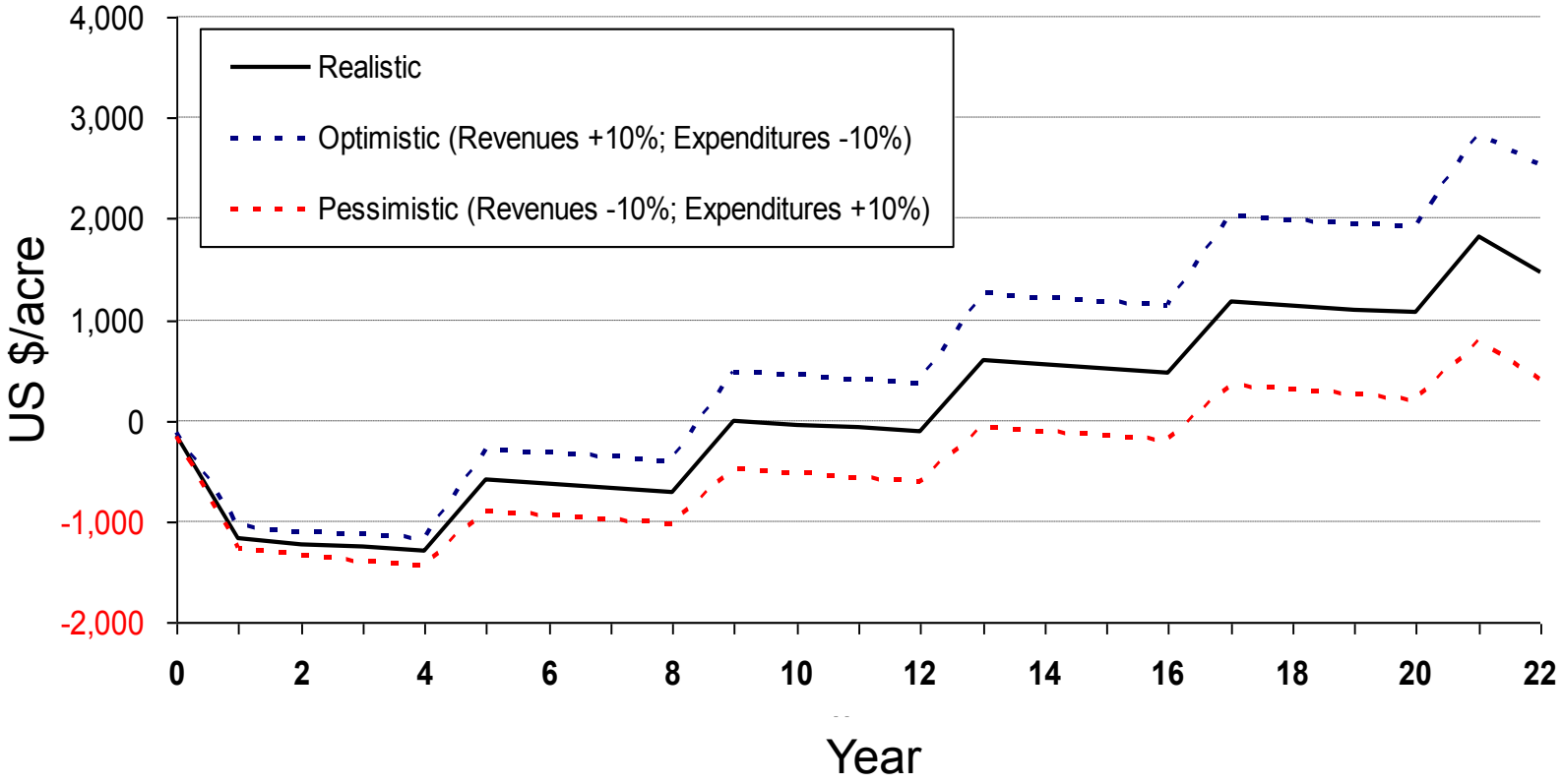
(Available to download from http://www.esf.edu/willow/download.asp/)

Economics of Willow – Base Case



Back to
Input-Output
Sheet

Accumulated cash flow in $ per acre



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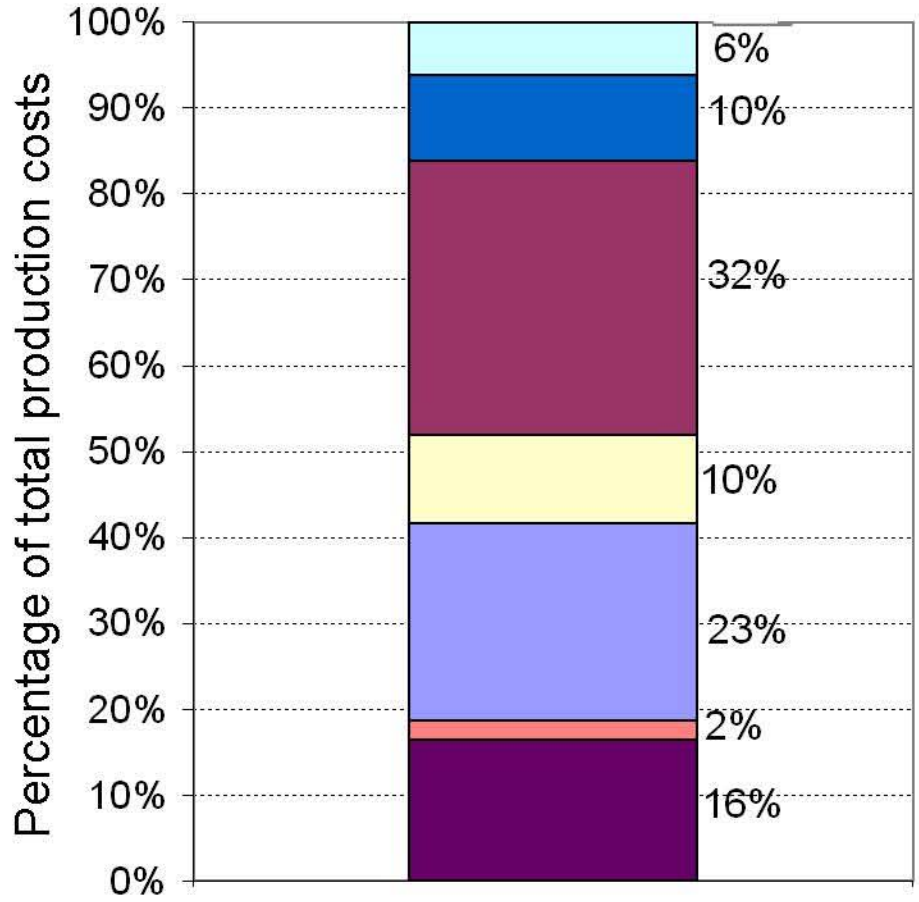
NPV: $209/acre IRR: 6.4%

Distribution of Costs



Stock removal	740 $ ha^{-1}
Transport	1,179 $ ha^{-1}
Harvest	3,778 $ ha^{-1}
Fertilizer	1225 $ ha^{-1}
Establishment	2,709 $ ha^{-1}
Administration	276 $ ha^{-1}
Land cost and insurance	1,955 $ ha^{-1}

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(Buchholz and Volk, in review)

LCA of Willow Crops - Boundaries

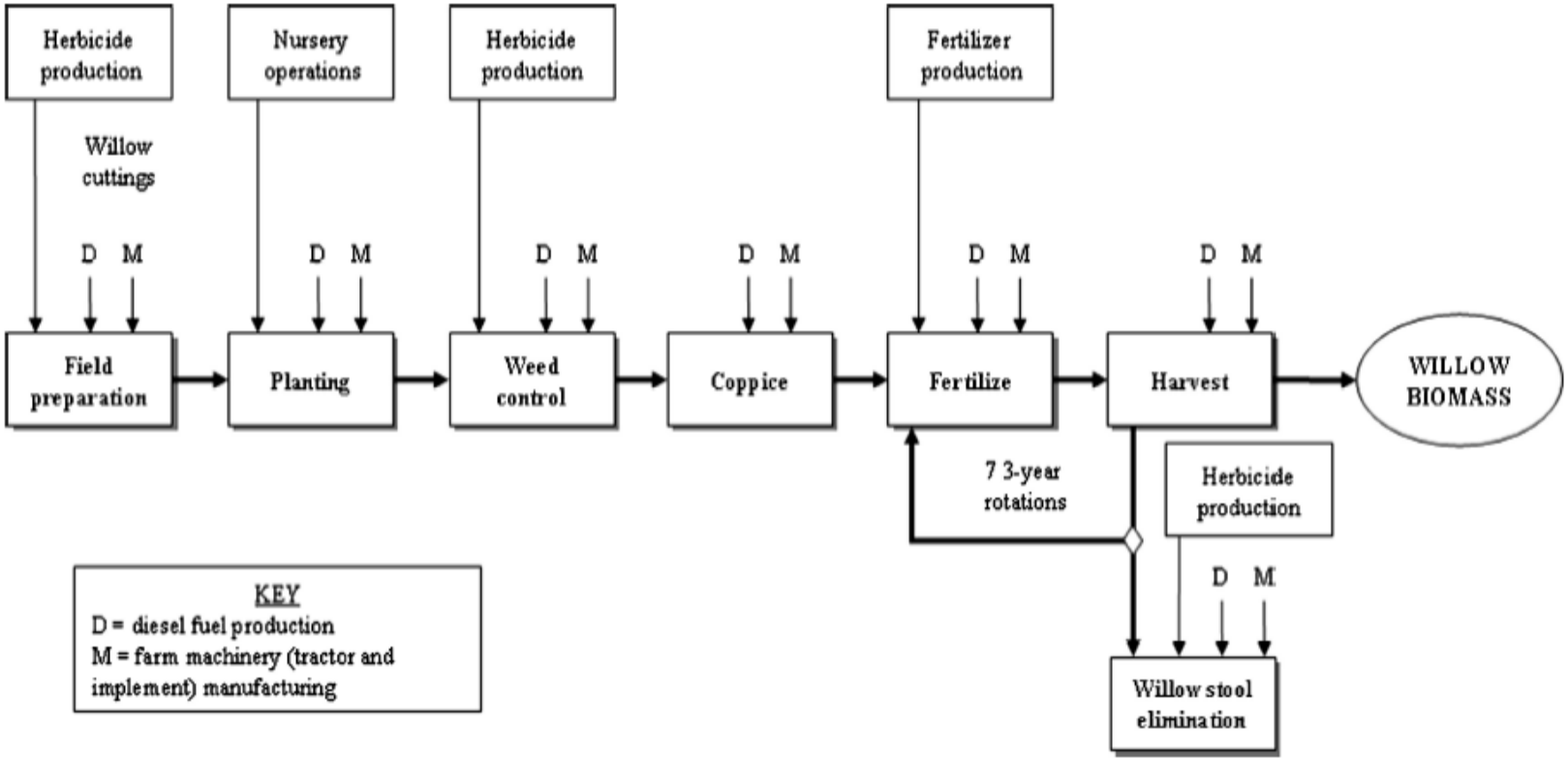

FIG. 1. Schematic of willow biomass production processes and inputs.

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(Heller et al. 2003)

Primary Energy Use

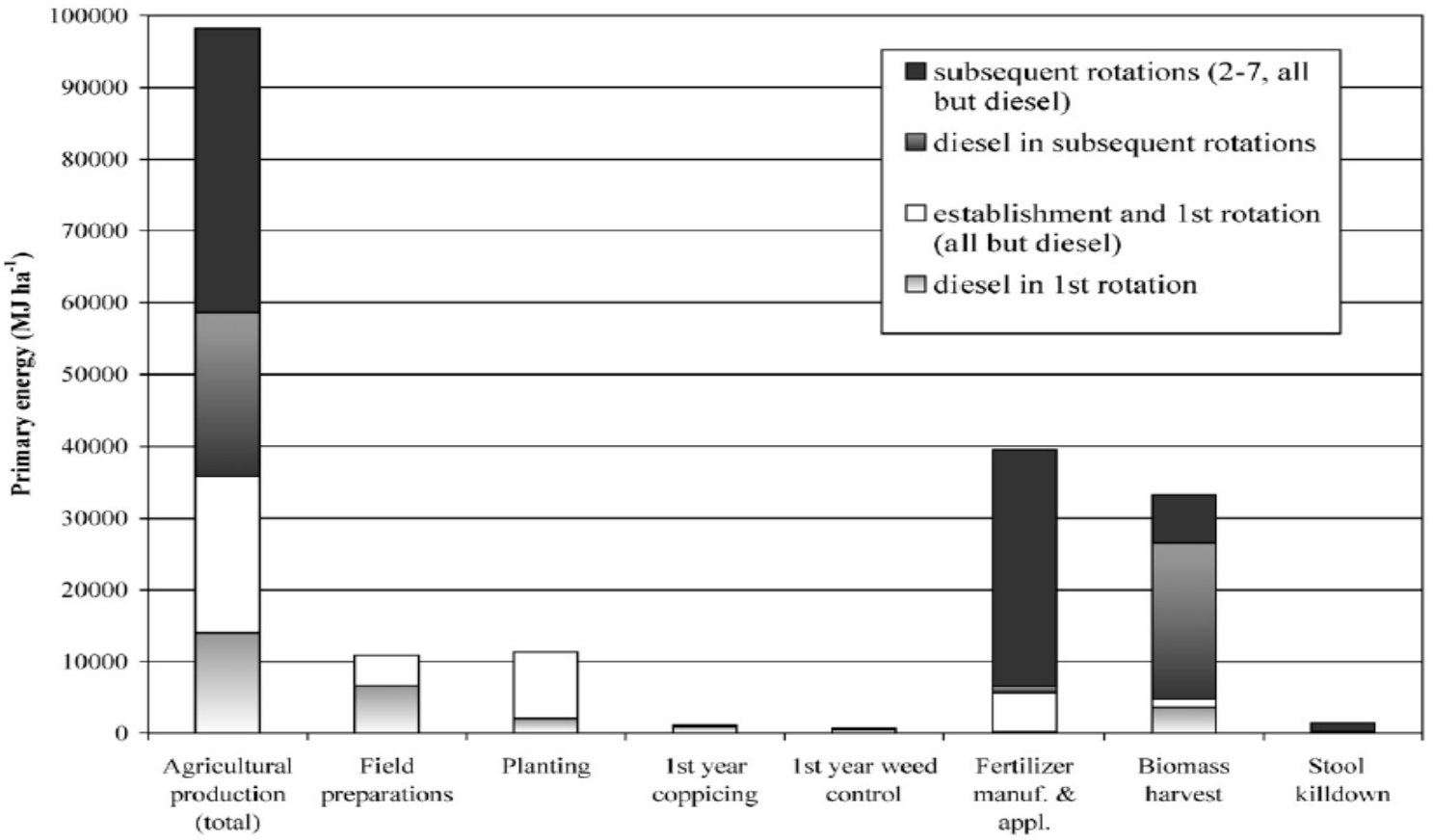

Fig. 2. Primary energy use for major cropping events during the 23 year lifespan of willow biomass crops in New York. "Field preparations" encompasses all of the tilling and weed control activities leading up to planting, including the manufacture of herbicidal inputs. "Planting" includes the nursery production of willow cuttings and the planting operation itself. "Fertilizer manufacturing and application" includes the manufacture and transportation of ammonium sulfate as well as field application of the fertilizer.

Developing Willow Harvesting Systems 2001-2003 - Bender

- Tractor mounted unit with new auger style chipper
- Even after several design changes to the chipper this unit produced stringy material

Developing Willow Harvesting Systems: 2004-2005

New Holland FX 45 forage harvester with a row independent corn head on willow biomass crops.

- Partnered with CNH starting in 2004 to develop a single pass willow harvesting system:
- Started with New Holland FX 45 forage harvester and row independent corn head
- First determine if FX45 forage harvester would effectively chip willow
  - ✓ Chipping was successful
  - ✓ Consistent product
  - ✓ Corn cutting head was not robust enough

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Developing Willow Harvesting Systems: 2006-2008

New Holland forage harvester with Coppice Resources Ltd (CRL) willow cutting head.

- CNH, SUNY-ESF and CRL developed a hydraulic driven willow cutting head based on standard CRL design in 2005/06
- Tested in 2006-2008
  - Effective in smaller diameter willow (<3”) or less dense stands
  - Problems with:
    - Inconsistent flow of willow stems into forage harvester
    - Larger diameter willow (>3”) in dense stands of older willow
    - Snow over 6” deep

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FR 9000 Coppice Header 130 FB

- CNH started development of the NH 130 FB coppice header for the new generation FR forage harvester in 2007
- Customer requirements
  - Harvest 1 or 2 rows
  - Maximum capacity 2 ha/h
  - Maximum stem diameter of 12-15 cm
  - No changes to feed rolls and chopper drum on base unit
  - Chip length of 10-45 mm

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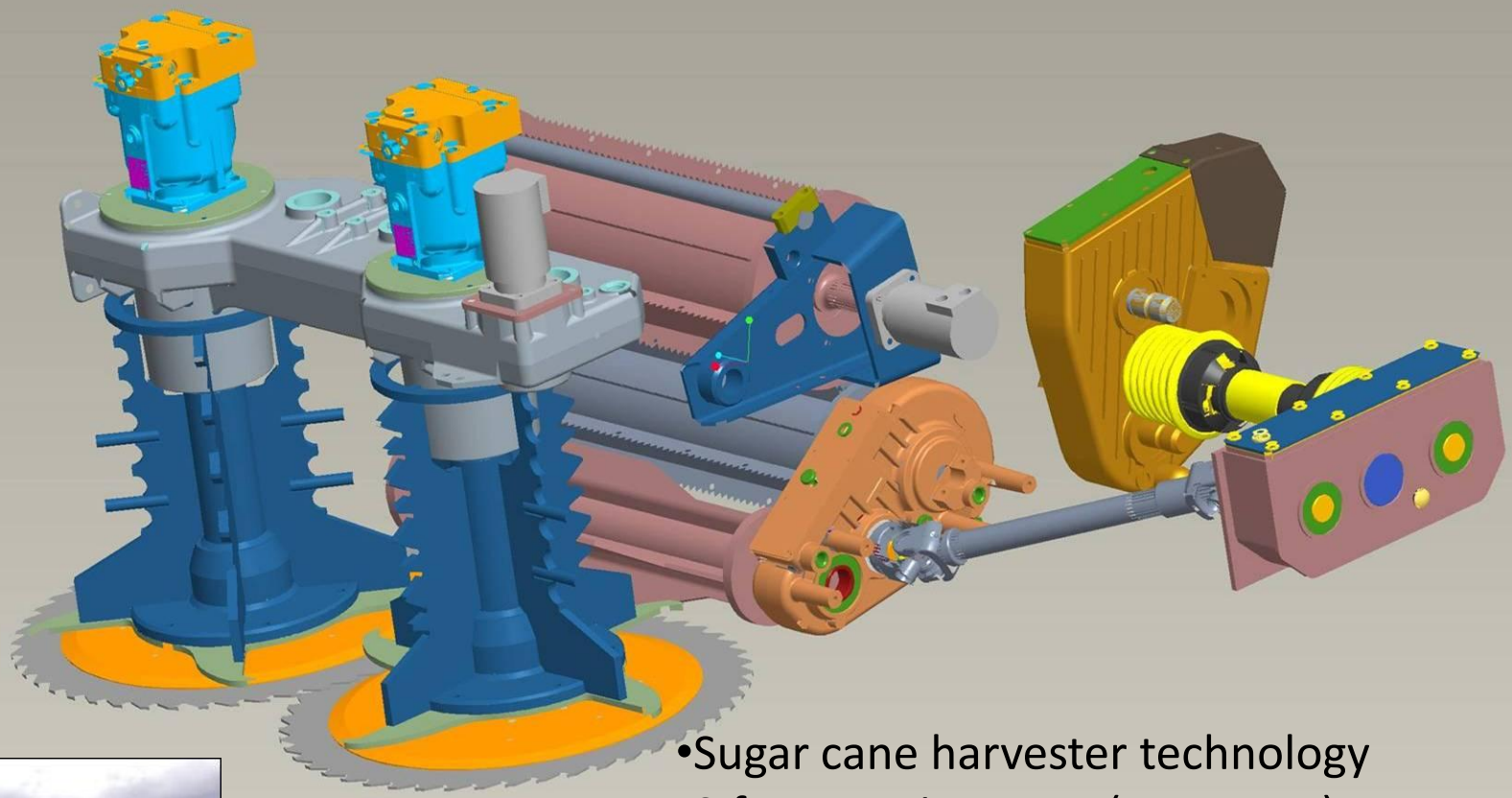
Header Drives & Components



- Sugar cane harvester technology
- 2 fast rotating saws (cut stems)
- 2 slow rotation feeding towers (center stems)
- 1 paddle roll (lift stems)
- 2 grab/feed rollers (pull and feed stems)
- Hydrostatic drive (in cab speed setting)

Developing Willow Harvesting Systems: 2008 - 2009

New CNH Short-Rotation Coppice header being tested on willow in NY

- Field trials with new coppice header mounted on a FR series forage harvester have been run on willow and hybrid poplar in the UK and U.S.
  - Harvest rates of up to 2 ha hr^{-1}
  - Stems up to 13 cm diameter

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Harvesting Willow Energy Crops

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Harvesting Hybrid Poplar

Testing has occurred in 3 – 5 year old hybrid poplar in the pacific northwest managed by GreenWood Resources

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Moving Chips from the Edge of the Field

Self-unloading forage wagons

Covered over-the-road trailers (30-36 tons of chips)

Moving Chips from the Edge of the Field

Forage dump wagon

Large forage dump wagon

Open top over-the-road trailer (25-30 tons of chips)

Effect of Rotation Length on Harvesting Costs

Rotation Length (years)	Biomass Production (odt ha^{-1})	Harvesting Costs ($ odt^{-1})	Project IRR (%)
3	33	16.3	5.5
4	44	14	6.2

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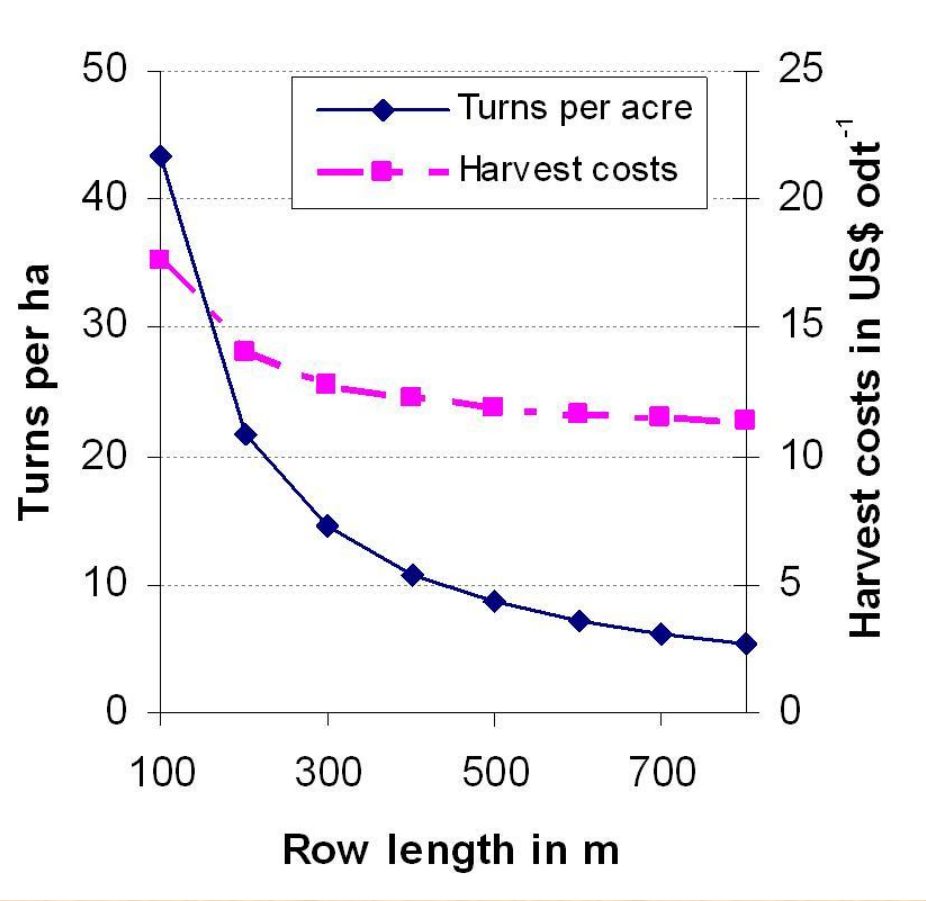
(Buchholz and Volk, in review)

Field Layout Influences Design



Effect of row length on harvesting costs in willow biomass crops

- Planning for harvesting starts when planting
- Longer rows reduces time spent turning equipment around and lowers harvesting cost
- Break point is about 300 – 400 m and may be limited by choice of collection equipment

(Buchholz and Volk, in review)

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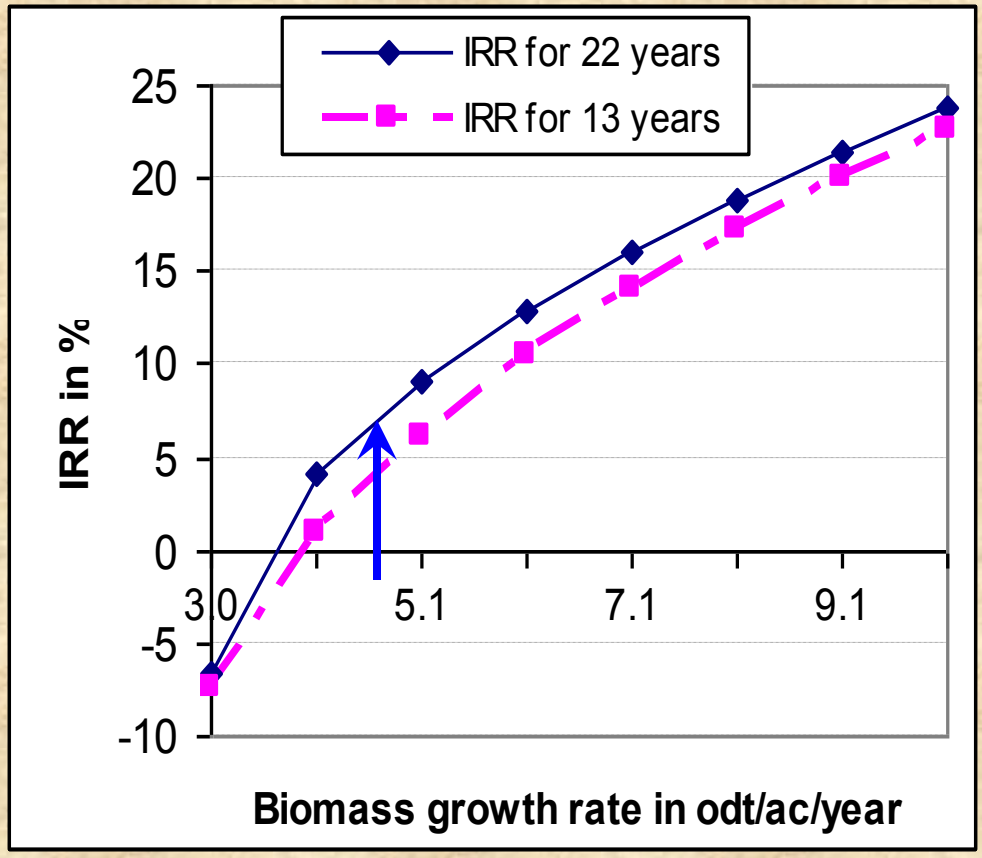
Effect of Increased Yield

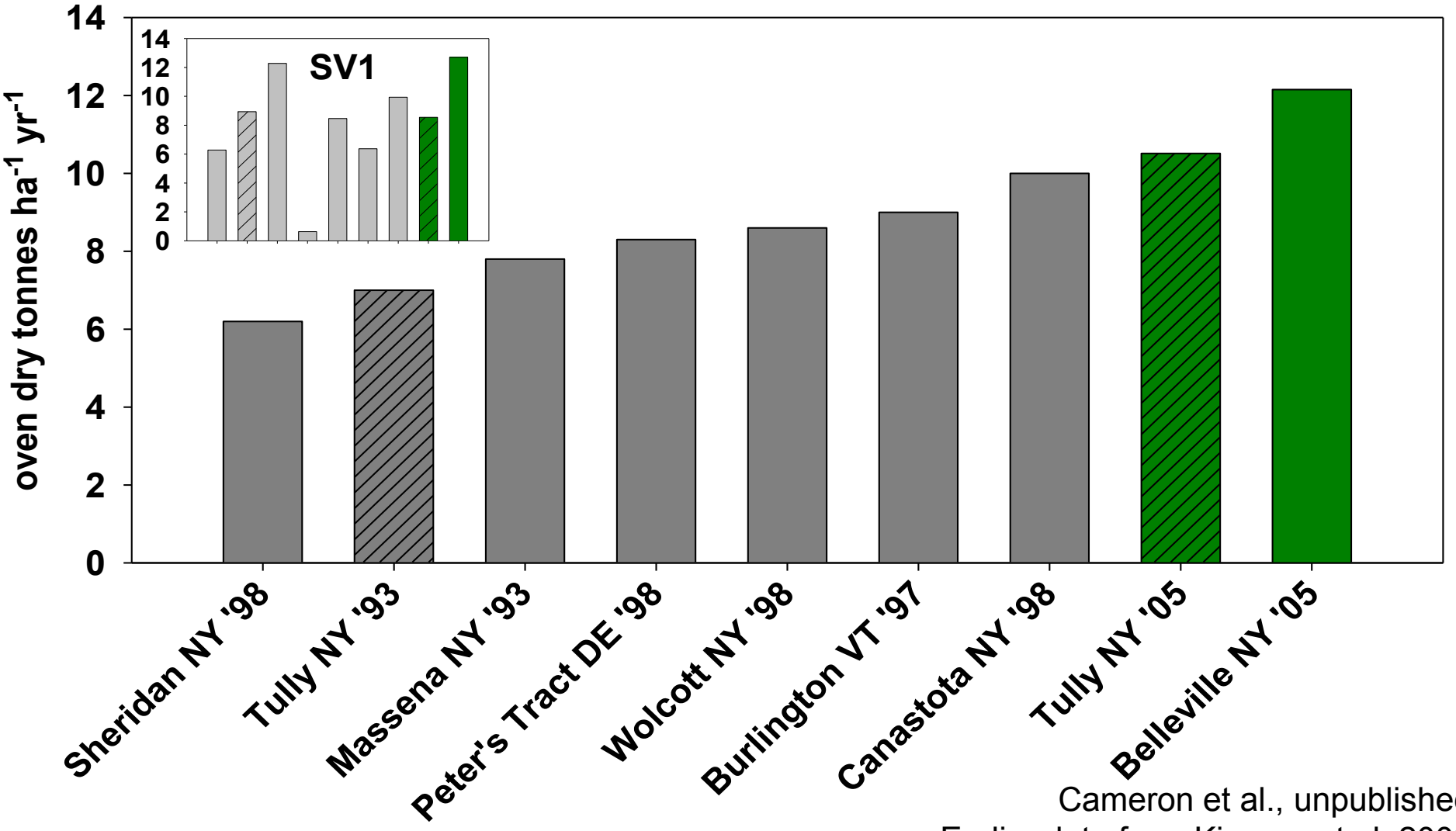


Effect yield on IRR of willow biomass crops (Buchholz and Volk, in review)

- With a base case yield of 5 odt ac^{-1} yr^{-1} (11.3 odt ha^{-1} yr^{-1}) internal rate of return is ~ 6%.
- A 50% increase in yield more than doubles the IRR
- Improve yield through
  - breeding and selection
  - enhanced crop management including weed control, variety selection, nutrient management, spacing, rotation length etc

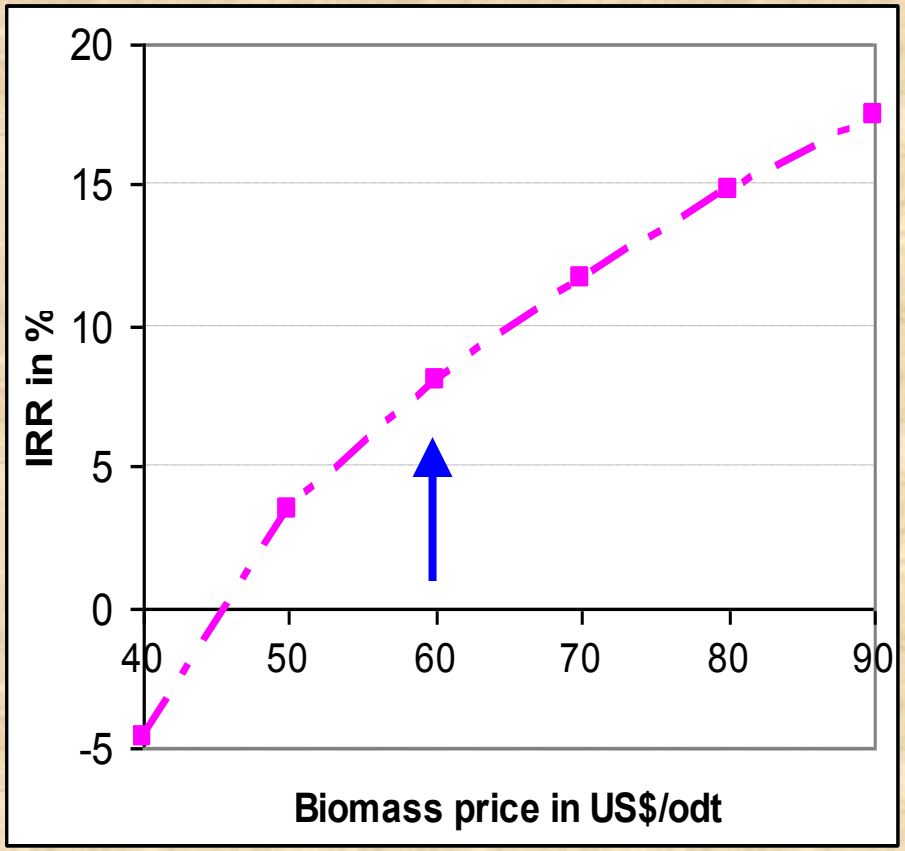
Mean Yield of Top Five Clones in Yield Trials

- New varieties contribute to 21% greater yield



Cameron et al., unpublished
Earlier data from Kiernan et al. 2003

Price for Biomass

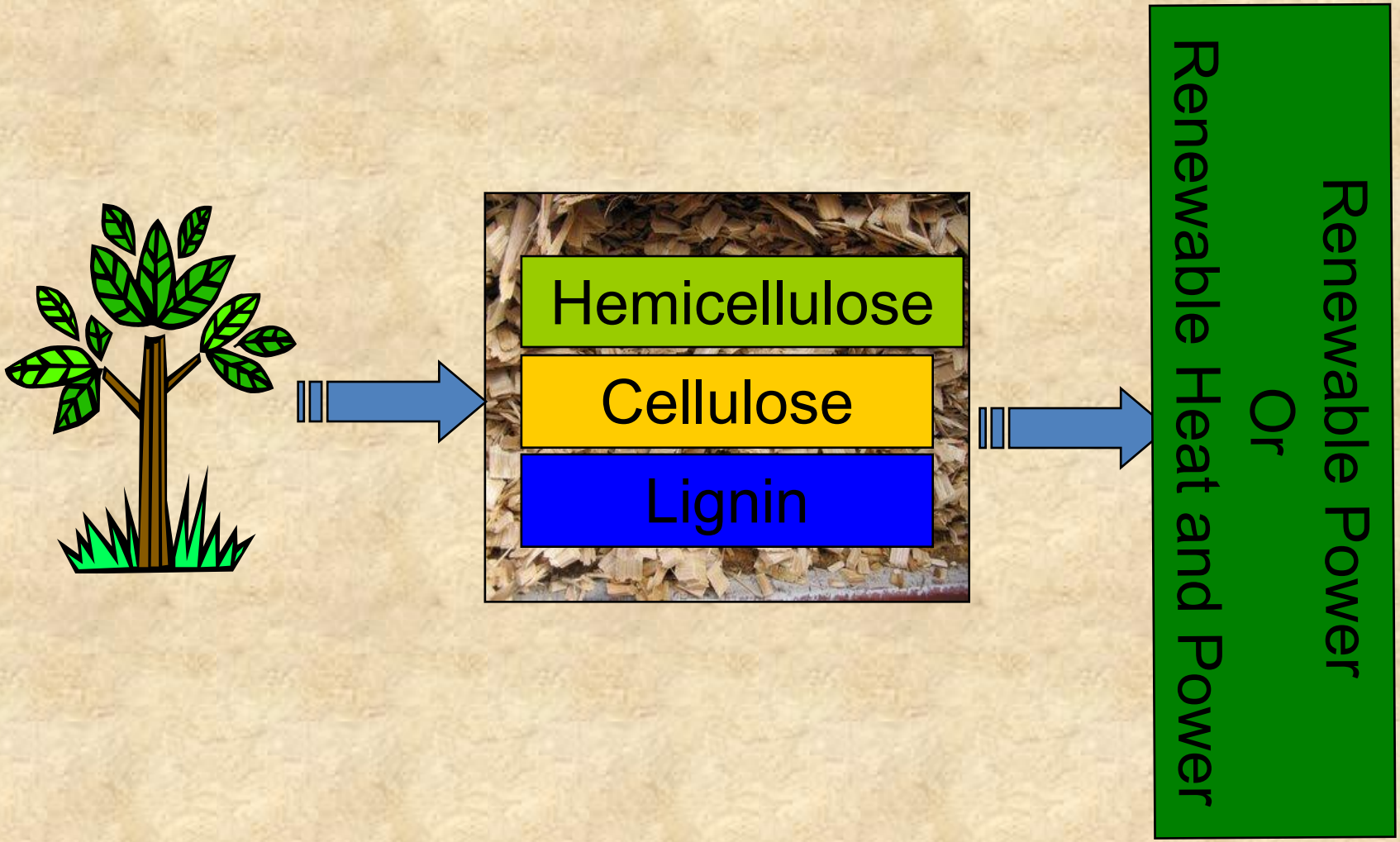


Effect of changes in the price for willow biomass on the crops IRR

- 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

(Buchholz and Volk, in review)

Current Wood to Energy Facilities



Wood to Energy Biorefinery

Water Extraction

(15 – 20% of mass)

Acetic acid

Ethanol

Biodegradable plastics

Hemicellulose

Chemicals

Renewable Heat and Power

Wood chips after two hours

Extract solution after two hours

Multiple Products from Wood

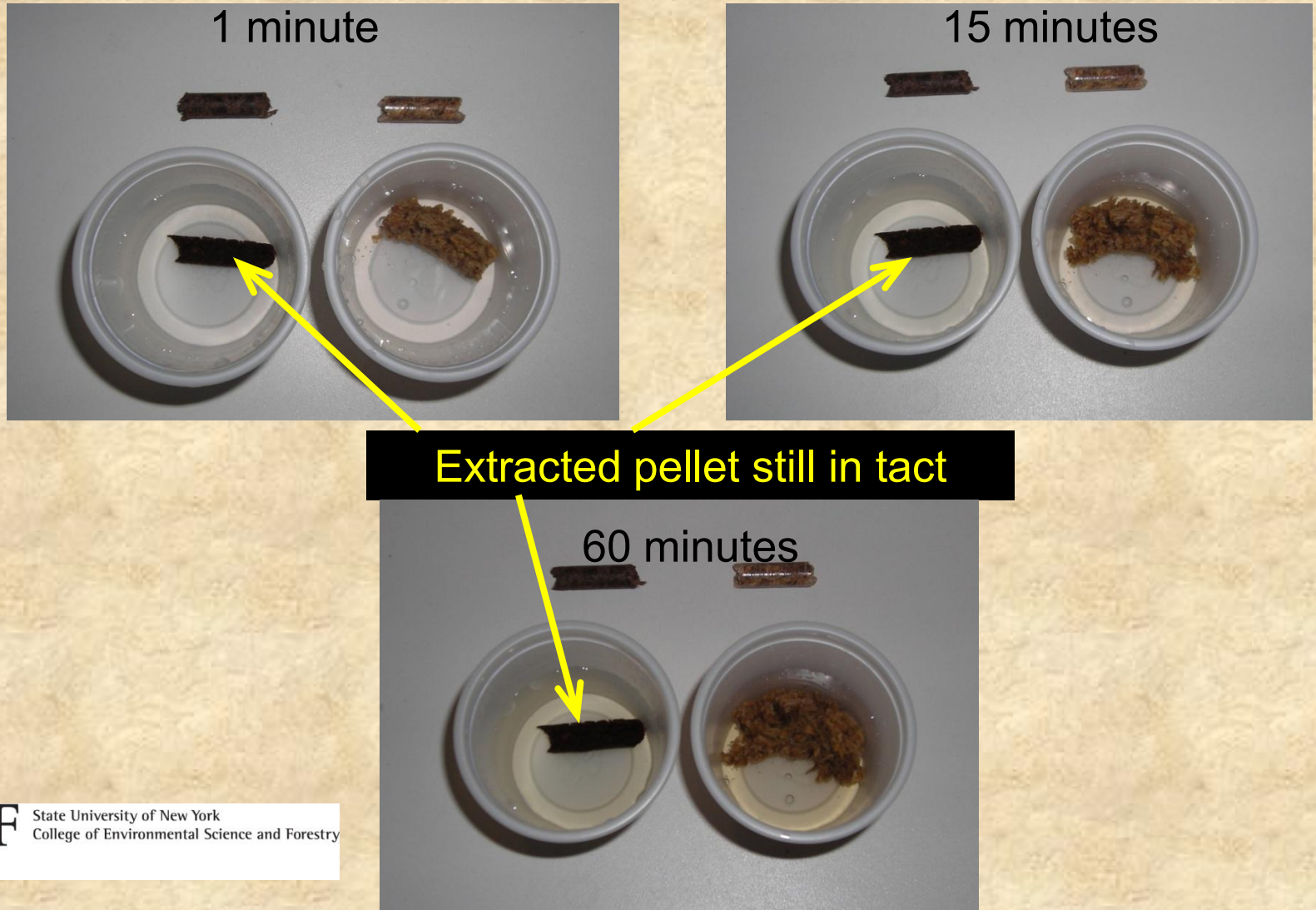
- After extraction:
  - Darker color
  - Structure still intact
  - Cellulose and lignin maintained
  - Same volume and shape
  - 20-23% lower mass
  - Lower ash content
  - Higher energy content

Multiple Products from Biomass

- Higher lignin content gives these pellets greater structural strength with fewer nubs
- Ash content is premium grade even from wood with bark
- Removal of hemicellulose makes wood less likely to reabsorb water

Multiple Products from Biomass

Submerge an extraction pellet & a conventional pellet in water



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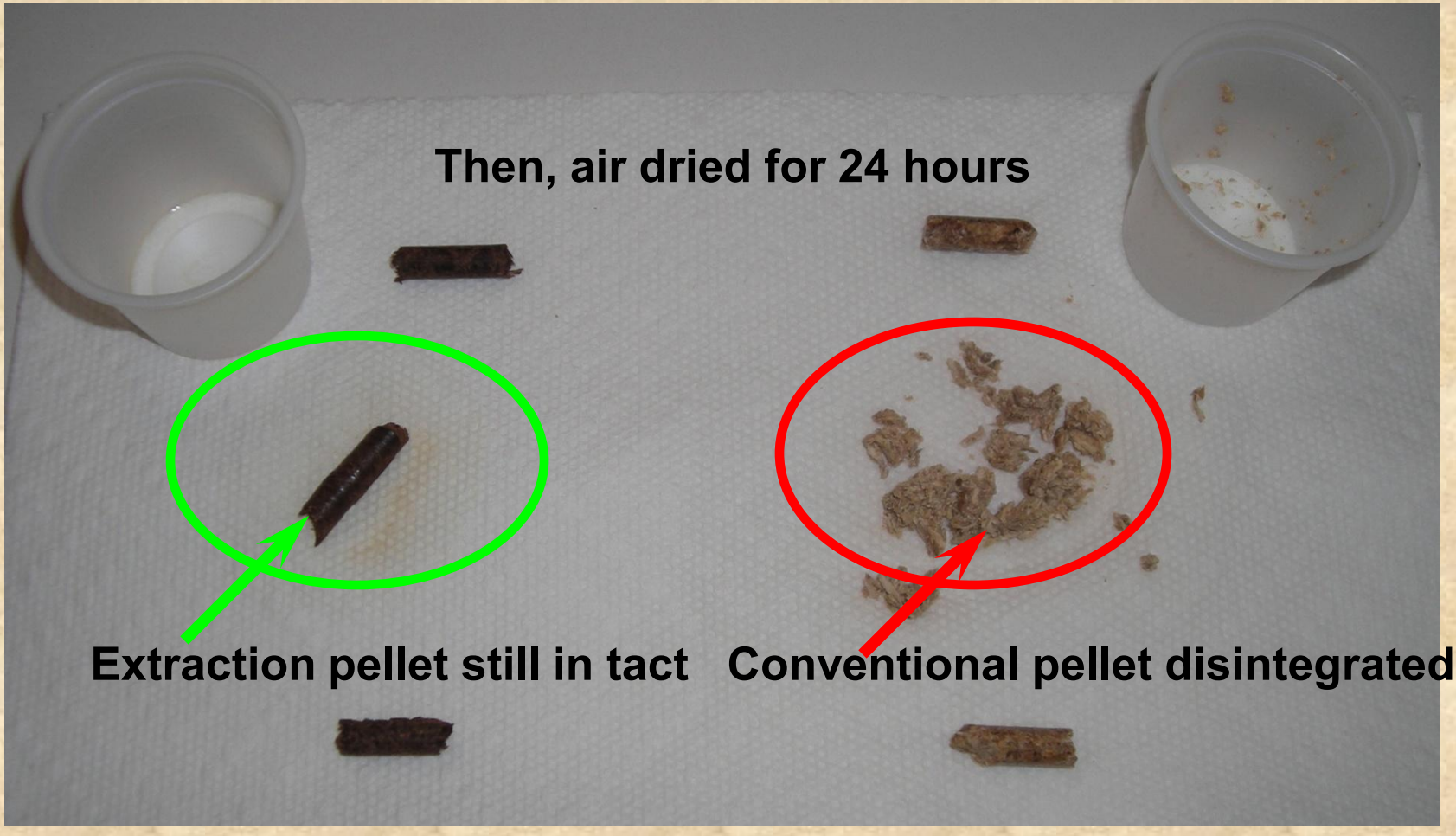
Multiple Products from Biomass



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Future Plans

- Testing NH forage harvester and coppice header in willow and hybrid poplar crops
  - different sizes, ages, varieties, times of year
- Optimize the harvesting and collection system
- Improve efficiency and effectiveness of harvesting system
- Test harvested willow and hybrid poplar biomass in biorefineries and adjust system to produce the most useable product

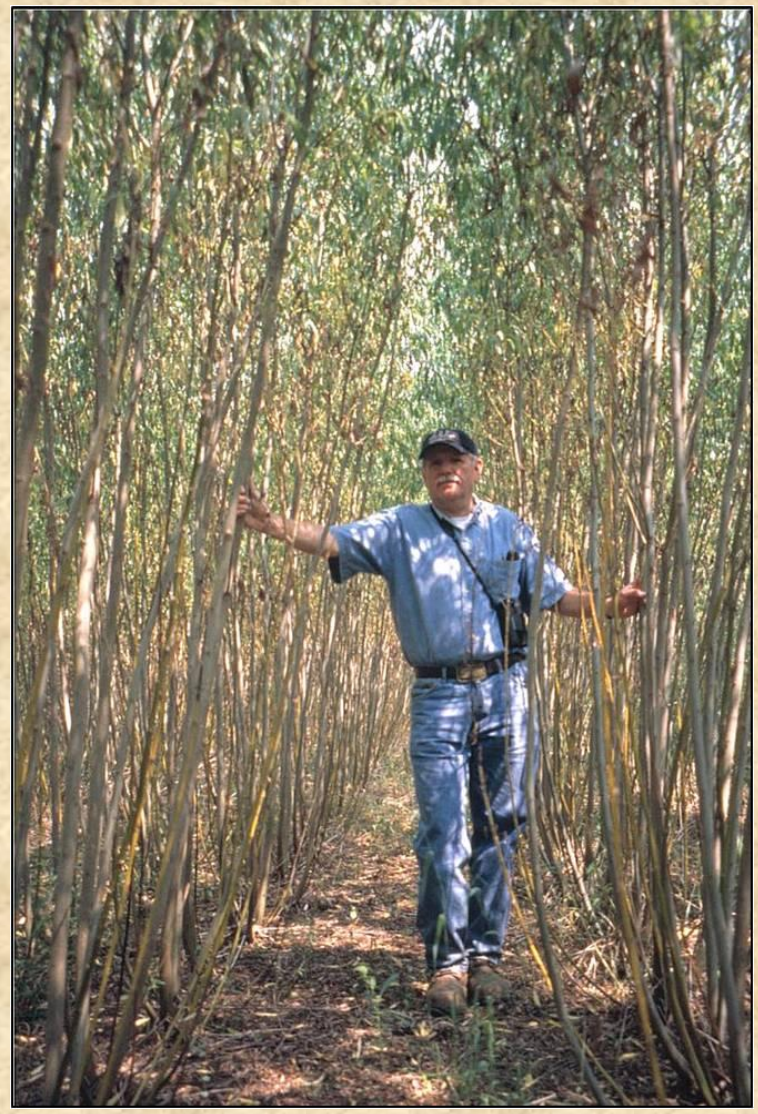
Summary

- Considerable progress has been made over the past decade in developing a harvesting system for willow energy crops in North America
- Developing the system for hybrid poplar energy crops
- Need to integrate the system being developed into field design and crop management recommendations
- Optimize system over the next two years

Acknowledgements

- NYSERDA – NY State Energy Research and Development Authority
- USDA CSREES
- USDA Rural Development
- US Department of Interior
- US DoE Biomass Program

Questions



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