2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

Development and Deployment of a Short Rotation Woody Crops Harvesting System Based on a Case New Holland Forage Harvester and SRC Woody Crop Header

Date: May 22, 2013
Technology Area Review: Feedstock Supply & Logistics

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Organization: SUNY-ESF

Project Partners: ESF State University of New York College of Environmental Science and Forestry; NEW HOLLAND AGRICULTURE; GreenWood Resources; Mesa Reduction Engineering & Processing, Inc.; ZeaChem; Applied Biorefinery Sciences
Funding by: U.S. Department of Energy, Energy Efficiency & Renewable Energy, Biomass Program; nyserda Energy. Innovation. Solutions.

Project Partners

ESF
State University of New York
College of Environmental Science and Forestry

GREENWOOD
RESOURCES
A Resource That Lasts Forever™

NEW HOLLAND
AGRICULTURE

ZeaChem

Applied Biorefinery Sciences

Mesa
Reduction Engineering & Processing, Inc.

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Goal Statement

Develop, test and deploy a single pass cut and chip harvester combined with a handling, transportation and storage system that is effective and efficient in a range of different short rotation woody crop (SRWC) production systems, environments and operating conditions across North America.

Quad Chart

Timeline

- Start Date August 2010
- End Date August 2013
  - No cost extension
- 75 – 80% completed

Budget

- Funding for FY11
  - ($353,701/ $724,218)
- Funding for FY12
  - ($405,894 / $310,419)
- Funding for FY13
  - $64,316 / $49848
- Forecast:
  - $509,907 / $249,332
- 2.75 years of funding at $299,604/yr.

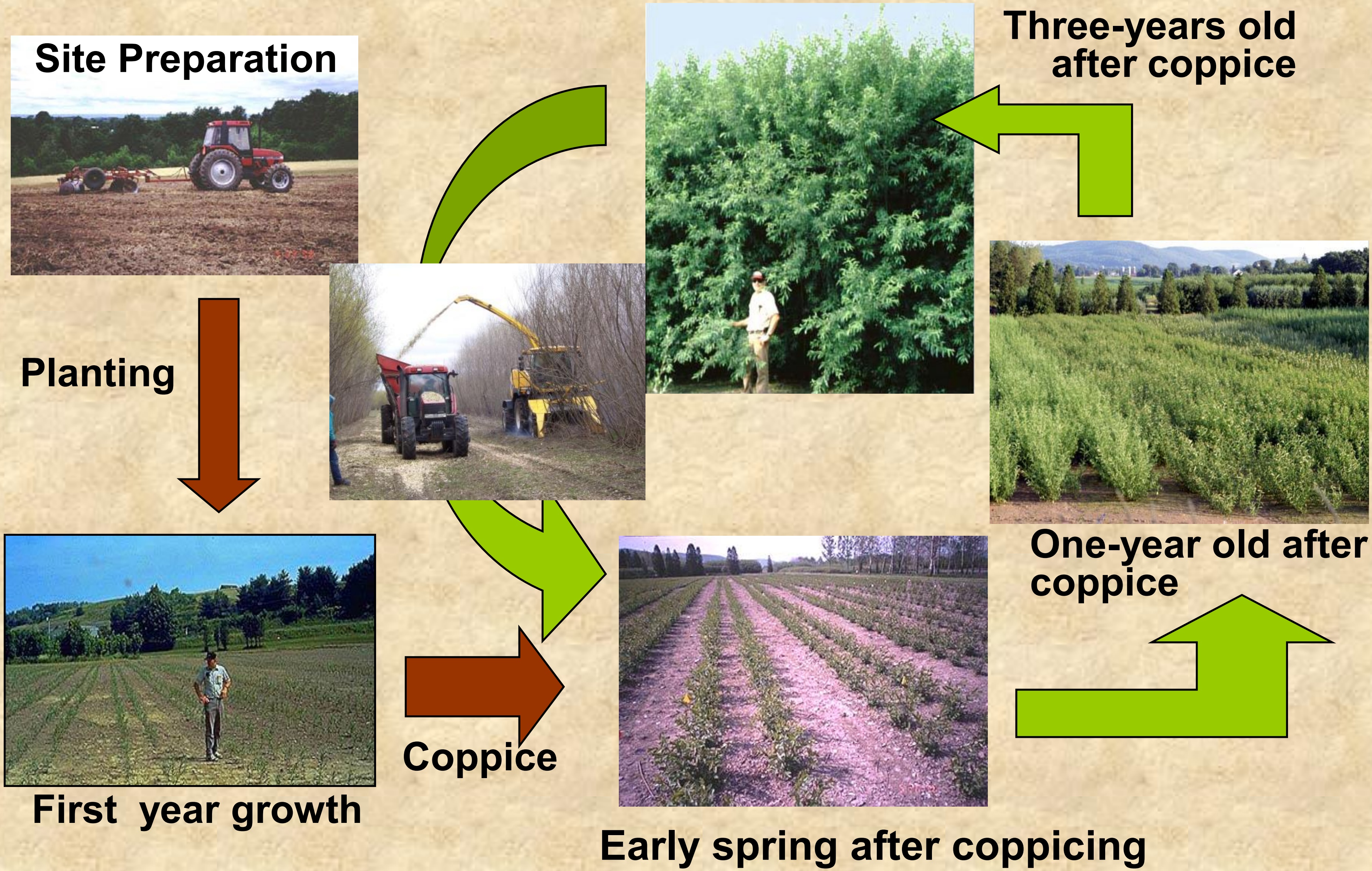
Barriers

- Barriers addressed
  - Ft-A. Feedstock Availability and Cost:
  - Ft-D. Sustainable Harvesting
  - Ft-G. Feedstock Quality and Monitoring:
  - Ft-H. Biomass Storage Systems:
  - Ft-L. Biomass Material Handling and Transportation
  - Ft-M. Overall Integration and Scale-Up

Partners

- SUNY-ESF – Project lead/ Willow harvesting/ Data processing
- Case New Holland - OEM
- Greenwood Resources – Hybrid poplar growth and harvesting
- Mesa Reduction and Engineering – transportation and logistics
- Zeachem and Applied Biorefinery Sciences – biorefinery partners

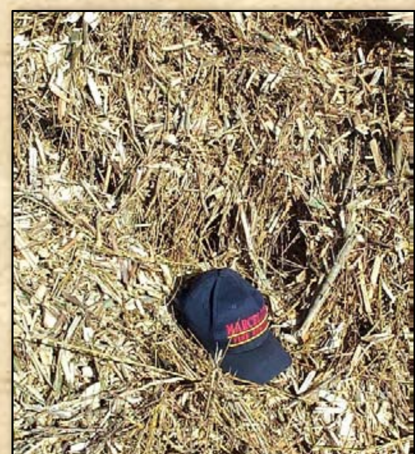
Willow Biomass Production Cycle

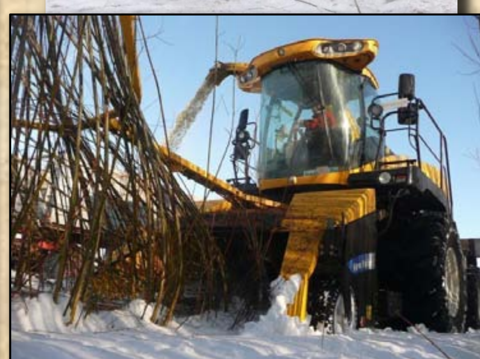


Project Overview

- 30% of delivered cost associated with harvesting and conveying materials to edge of field
  - With transportation to end user included 45-60% of costs
- Harvesting is second largest source of GHG, transportation of biomass is first
- Commercial markets are developing and this system is the current state of the art for SRWC
  - GWR / Zeachem
  - Northern NY BCAP / ReEnergy
- This project has already provided direct benefit to these scale up efforts

Developing a Harvesting System 2001-2008





- Issues with earlier harvesting systems
  - Inconsistent chip size and quality
  - Durability of harvester
  - Stem size limitations
  - Header feeding issues
  - Reliability

Developing a Harvesting System 2008 - Present

- **NH** FR-9000 series forage harvester
- CNH developed 130-FB Coppice Header

❖ Objectives

- Stems up to 130 mm diameter
- Chip length of 10-45 mm
- Harvest 1 or 2 rows
- Harvest rate up to 2 ha hr^{-1}
- No changes to feed rolls and chopper drum on base unit

1 - Approach

- Team of crop production, equipment engineers and operators, biorefinery partners so multiple concerns and objectives are met simultaneously
- Iterative optimization of New Holland short rotation coppice header for willow and hybrid poplar
  - Engineering and development of specialized cutting head
  - Field testing in willow and hybrid poplar crops and monitoring system performance and chip quality
  - Modify/improve system and conduct field tests
- Four Task Areas
  - Task 1 - Harvesting and Equipment
  - Task 2 - Collection Systems
  - Task 3 - Chip Quality
  - Task 4 - Assess Economics / Cash Flow Modeling

2 - Technical Accomplishments/ Progress/Results

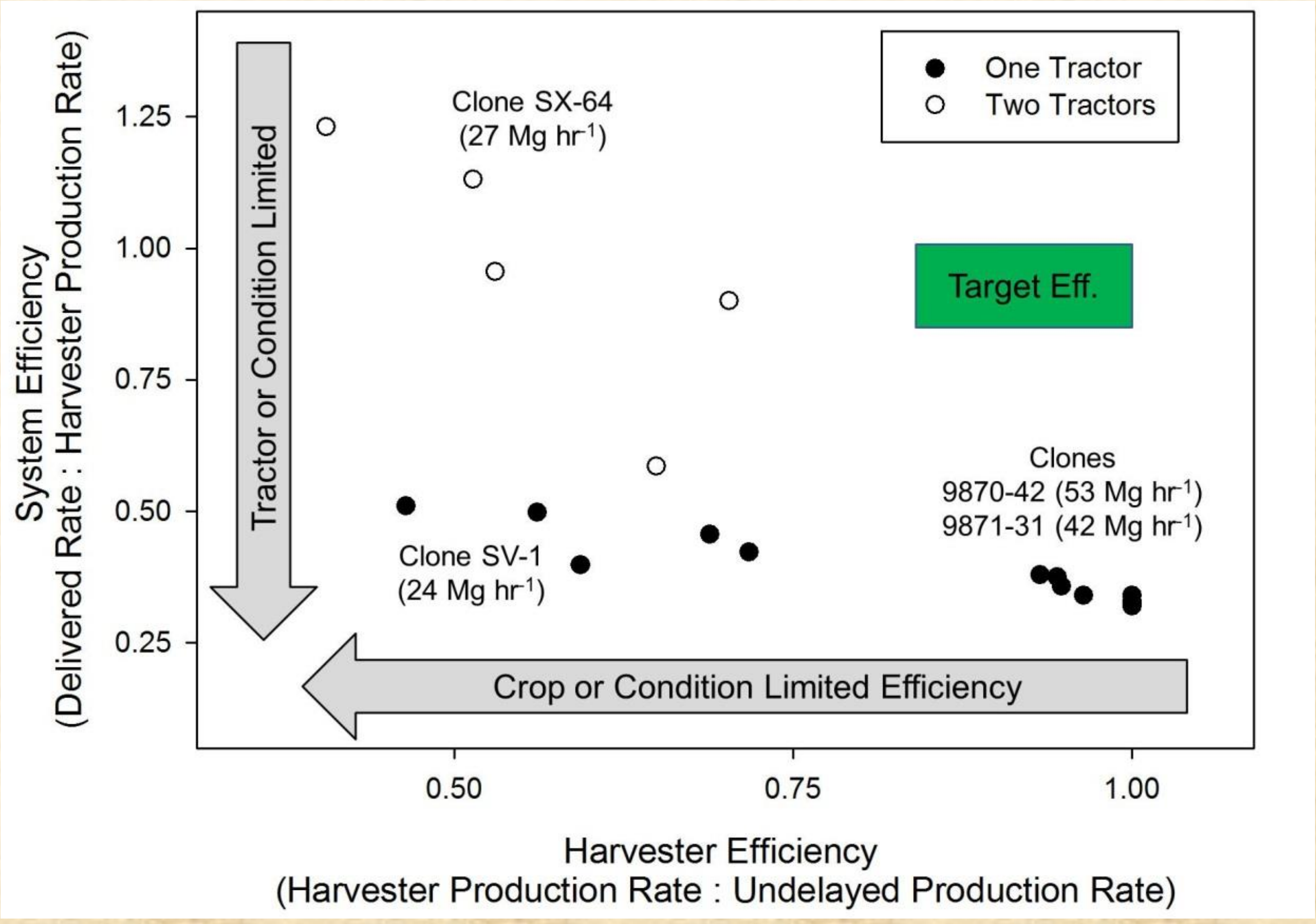
- **Task 1.** Develop, tune, test and deploy a single-pass cut and chip harvesting system that can be used in a range of willow and hybrid poplar cropping systems across the United States.

Harvest Season	Hectares Monitored (ha)	Harvest Rates (ha hr^{-1})	Production Rates (Mg hr^{-1})	Harvester Down Time (%)
2010	5	0.5	9	74
2011-12	12	0.75 - 3	36	20
2012-13	100	0.5 - 4	35-41	Harvester Negligible

- Key Milestones
  - Improved harvester performance and reliability – Not the limiting factor
  - Improved data methodology and acquisition
  - Identified key areas for improvements in next phase

2 - Technical Accomplishments/ Progress/Results

•**Task 1.** Develop, tune, test and deploy a single-pass cut and chip harvesting system that can be used in a range of willow and hybrid poplar cropping systems across the United States.



2 - Technical Accomplishments/ Progress/Results (cont'd)

•**Task 1.** Develop, tune, test and deploy a single-pass cut and chip harvesting system that can be used in a range of willow and hybrid poplar cropping systems across the United States.

•Mechanical/Physical changes to harvester

- Tested a variety of saw blade designs and tips
- Modified push bar with a divider to enhance crop flow
- Reinforced feed rolls and paddle rolls for reliability
- Added plate for gear box to stop material from wrapping and support crop flow

2 - Technical Accomplishments/ Progress/Results (cont'd)

- **Task 2.** Develop and refine one or more handling systems that will effectively and efficiently move SRWC chips produced with the harvester in Task 1 from the field to the end user.






- Key Milestones
    - Tested and collected data from a number of systems
    - Key inputs for optimization modeling with IBSAL

2 - Technical Accomplishments/ Progress/Results (cont'd)

•**Task 2.** Develop and refine one or more handling systems that will effectively and efficiently move SRWC chips produced with the harvester in Task 1 from the field to the end user.

	Equipment				
	Small-Medium Dump Wagons/Carts	Self-Propelled Wagons	Cane Wagons	10-Wheeled Trucks	18-Wheeled Trucks
Capacity (Mg)	4-8	4-5	10-12	12-14	12-22
Operating Cost	Low	Medium	Medium	Medium	High
Local Availability	High	Low	Low	Medium	High
Able to Load Semi-Truck at Field Edge	No	No	Yes	No	N/A
Maneuverability	Fair-Excellent	Excellent	Excellent	Fair-Good	Poor
Cycle Time	Good	Poor	Excellent	Good	Poor
Operability on Soft Ground	Excellent	Excellent	Good	Poor	Impossible
Estimated Range to Unloading	< 1-3 km	< 1-3 km	<2-5 km	< 50 km	> 2 km
Durability in SRWC, Especially Related to Tire Punctures	Variable	Good	Excellent	Fair	Poor
Primary Limitations	(1) Capacity (2) Wheel Spacing	(1) Capacity (2) Cycle Time	(1) High Center of Gravity	(1) Tire damage (2) Sensitive to Field Layout and Headlands	(1) Turning radius (2) Effective Capacity

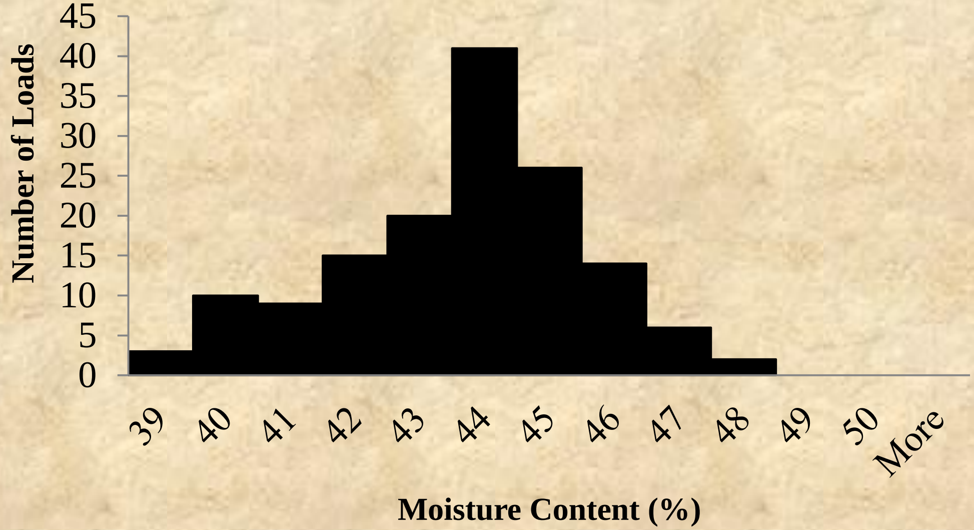
2 - Technical Accomplishments/ Progress/Results (cont'd)

•**Task 3.** Monitor changes in wood quality for chips of different sizes, harvested at different times of the year, and stored under a variety of conditions.

• Collected individual samples from ~250 truckloads during harvesting operations

    • Conducting analysis for moisture content, particle size, ash

• Relate sample characteristics to harvesting speeds, willow clone, outdoor temperature etc.



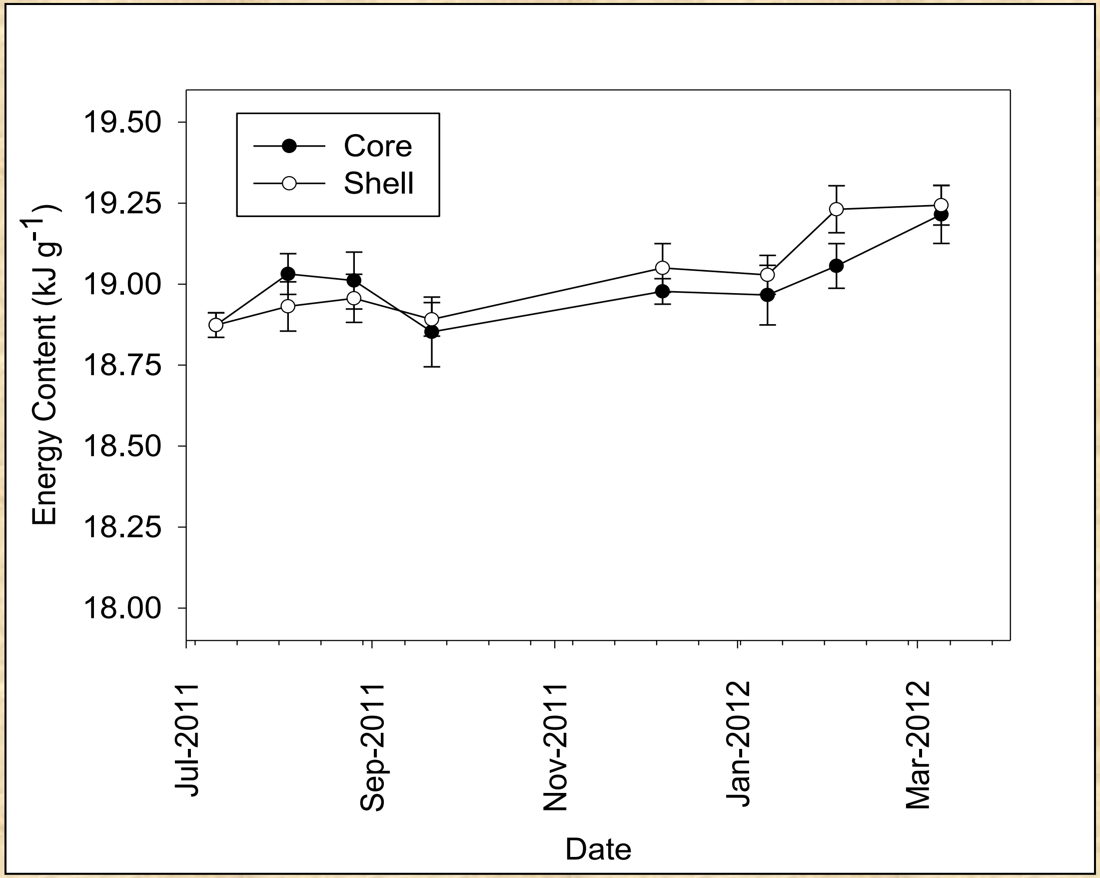
Distribution of moisture content of willow chips harvested in 2012

2 - Technical Accomplishments/ Progress/Results (cont'd)

•**Task 3.** Monitor changes in wood quality for willow and hybrid poplar chips of different sizes, harvested at different times of the year, and stored under a variety of conditions.

•Built and monitored chip piles from harvest in NE and PNW

Changes in energy content of willow chips stored in a pile in NY



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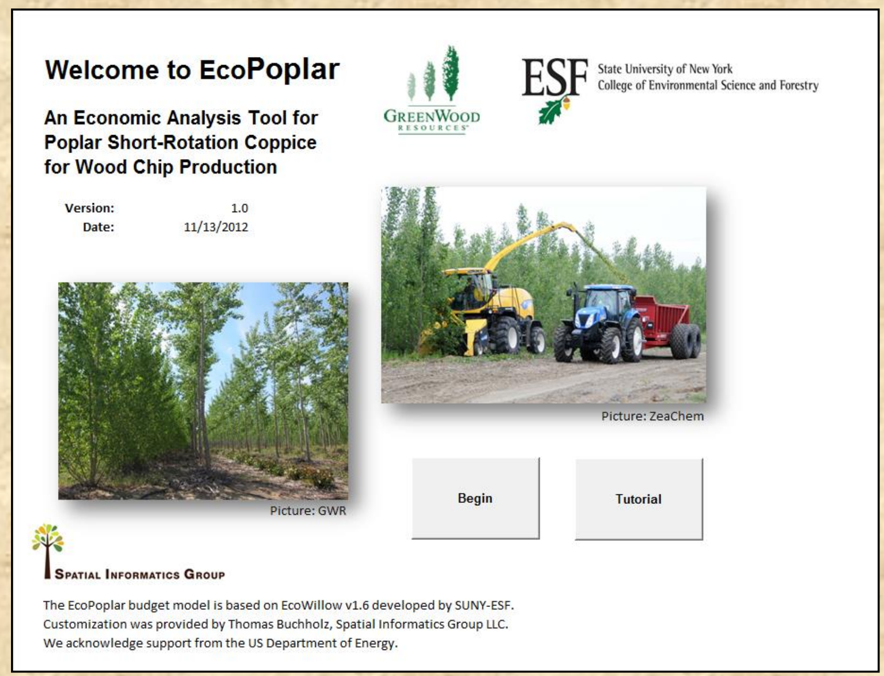

- Developed cash flow model for hybrid poplar system in PNW
- Updated willow cash flow model
- Improvements in harvester production and reliability reducing harvesting costs by ~50% from baseline (~40/odt)

3 - Relevance

- **Ft-A. Feedstock Availability and Cost**
  - Providing field data for harvesting and logistics for SRWC in two regions – PNW, NE
  - Will be used for logistics and economic analysis

- **Ft-D. Sustainable Harvesting**
  - Measuring material left behind by harvester to assess nutrient retention/removal
  - Running field operation to minimize soil impacts

- **Ft-G. Feedstock Quality and Monitoring**
  - Consistent quality product being generated by harvester
  - Collecting samples from large scale harvesting operations to quantify their quality.
  - Loads can be traced to specific clones, and the environmental conditions that they were harvested (such as how temperature affects chip quality, or how chip quality changes over the course of the harvest).

3 - Relevance

- **Ft-H. Biomass Storage Systems**
  - Leaf-on and leaf-off willow and poplar chip piles have been created and are being monitored

- **Ft-L. Biomass Material Handling and Transportation**
  - Tested numerous types of chip-handling equipment (semi trucks, silage trucks, cane-wagons, self-propelled wagons, ubiquitous dump wagons and carts).
  - Data will be used as inputs with modelers to develop an optimized system

- **Ft-M. Overall Integration and Scale-Up**
  - System is being expanded in both PNW and NE
  - Leveraged BCAP installations in both locations with end users ZeaChem and ReEnergy
  - Interface with modelers to help us design an optimized logistics supply chain

4 - Critical Success Factors

Harvesting willow biomass crops in central NY in November 2012

- Harvester reliability greatly improved
  - NH is marketing the FB 130 cutting head worldwide
  - Created commercial interests by engaging custom harvesters in both the PNW and NE regions
  - Demonstrated success in harvesting systems has provided end users and growers a degree of confidence to pursue willow biomass use and acreage expansion
    - USDA BCAP project in northern NY includes almost 1,200 acres of willow and a 10 year commitment from ReEnergy Holdings to purchase all the biomass

4 - Critical Success Factors

Harvesting willow biomass crops in central NY in November 2012

- Field data that will allow modeling and optimization of the system has been collected
- Initial analysis indicates that harvesting costs have been reduced by about 50% from baseline numbers at the beginning of the project
- Confidence provided for expansion of SRWC in PNW and the NE regions

5. Future Work

- DOE project ends in August 2013, NYSERDA cost share support ends December 2013
- Complete analysis of time-motion data collected in past 6 months
- Provide data to parameterize IBSAL model
- Finish characterization of ~250 samples collected during harvesting operations
- Update and run cash flow models for willow and poplar using inputs from field trials to determine harvesting costs
- Complete chip pile storage study and analysis
- Complete final report and draft journal articles

Summary

- Developed reliable harvesting system that generates consistent quality material
- CNH is marketing harvesting head around the world
- Tested and collected data on a range of chip collection systems that will allow optimization modeling to occur
- Harvesting costs of decreased about 50% from baseline trials at the start of the project
- ZeaChem and GreenWood Resources engaged in long term supply agreement for poplar biomass
- Demonstration of harvesting system provides confidence for next level of expansion of willow biomass crops in NE
- Next steps to reduce harvesting and logistics costs have been identified

Additional Slides

ANYWHERE APPROPRIATE

Responses to Previous Reviewers' Comments

- 1) Conversion partners appear to have a fairly minor role in the project and may not conduct conversion yield studies that would inform management of seasonality for harvest, storage requirements, freshness, etc.
  - Conversion partners have provided input on material produced from harvesting operations
  - ABS has conducted both small and pilot scale tests with willow and is confident in results
- 2) Evidence of Biorefinery Feedback or end-user engagement
  - ZeaChem moving ahead with plans to use poplar as a feedstock in biorefinery in Boardman, OR and has long term supply agreement with GreenWood Resources
  - ReEnergy has singed long term agreements for willow over the next 10 years

Publications, Presentations, and Commercialization

- Volk, T.A. 2011. Development of short rotation woody crops for the Northeast U.S. Binghamton University, November 28, 2011.
- Volk, T.A., L.P. Abrahamson, P. Castellano, M. Eisenbies, C. Foster D. Lewis, M. McArdle, J. Posselius, R. Shuren, B. Stanton, B. Summers. 2012. Development of a harvesting system for short rotation woody crops. Bioenergy Symposium, State College, PA, February 29, 2012.
- Eisenbies, M.H. L.P. Abrahamson, P. Castellano, C. Foster, D. Lewis, M. McArdle, J. Posselius, R. Shuren, B. Stanton, B. Summers, T. Volk. 2012. Development and deployment of a short rotation woody crops harvesting system based on a New Holland forage harvester and SRC woody crop header. Bioenergy 2012, Washington DC. July 10, 2012.
- Abrahamson, L., P. Castellano, M. Eisenbies, C. Foster, D. Lewis, M. McArdle, J. Posselius, R. Shuren, B. Stanton, B. Summers, T. Volk, J. Zerpa. Supply Systems for Short Rotation Woody Biomass. ASABE, Dallas, TX. July 31, 2012.
- Eisenbies, M.H., L.P. Abrahamson, P. Castellano, C. Foster, M. McArdle, J. Posselius, R. shurn, B. Stanford, B. Summers, T.A. Volk, J. Zerpa. 2012. Development and deployment of a short-rotation woody crop harvesting system based on a New Holland forage harvester and SRC woody crop header. Sun Grant Initiative National Conference, New Orleans, October 2 – 5.
- Volk, T.A. Production of willow biomass crops. Cornell Willow Field Day, Geneva, NY, Dec. 18, 2012.
- Lewis, D. 2012. Willow harvesting. Cornell Willow Field Day, Geneva, NY, Dec. 18, 2012.