2015 Project Peer Review

Improved Advanced Biomass Logistics Utilizing Woody Feedstocks in the Northeast and Pacific Northwest

March 8, 2017

Feedstock Supply and Logistics

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Goal Statement

- Goal is to lower the delivered cost of woody crops (hybrid poplar and willow) by optimizing harvesting and logistics supply systems while maintaining biomass quality along the supply chain:
  - $84 dry ton total cost to throat of conversion reactor
- Aligns with BETO mission and goals:
  - (1) Develop and demonstrate transformative and revolutionary bioenergy technologies.
  - (2) Enable national biofuels production to reduce dependence on foreign oil
  - (3) Encourage domestic bioenergy and bioproduct industry

Quad Chart Overview

Timeline

- Start: Q1 2015 but contract in June 2016
- End: Spring 2019
- Ongoing project

Budget

	FY15	FY16	FY17	Total planned funding (FY16-Project End Date
DOE Funded	205,759	196,306	497,134	$2.3 million
Project Cost Share (Comp.)*	470,649	337,359	334,423	$1.5 million

*If there are multiple cost-share partners, separate rows should be used.

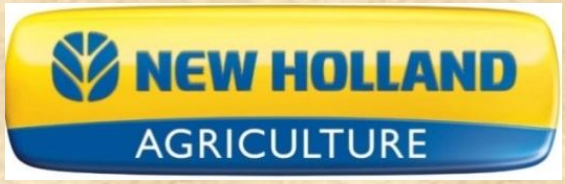
Barriers Addressed

- Ft-A. Feedstock Availability and Cost
- Ft-D. Sustainable Harvesting
- Ft-E. Terrestrial Feedstock Quality, Monitoring, and Impact on Conversion
- Ft-F. Biomass Storage Systems

Partners

- SUNY ESF
- GreenWood Resources
- ORNL – WVU – INL (modeling)
- Applied Biorefinery Sciences
- ZeaChem
- Case New Holland
- Honeywell International
- Celtic Energy and ReEnergy

1 - Project Overview – Project Partners



1 - Project Overview

- **Previous project (August 2010 to August 2014)**
  - Primary focus was on the development and performance of a cut and chip harvester system for SRWC
    - Increased performance, lowered costs, consistent quality
  - Harvesting and logistics is 40 – 60% of SRWC biomass cost

Video

1 - Project Overview





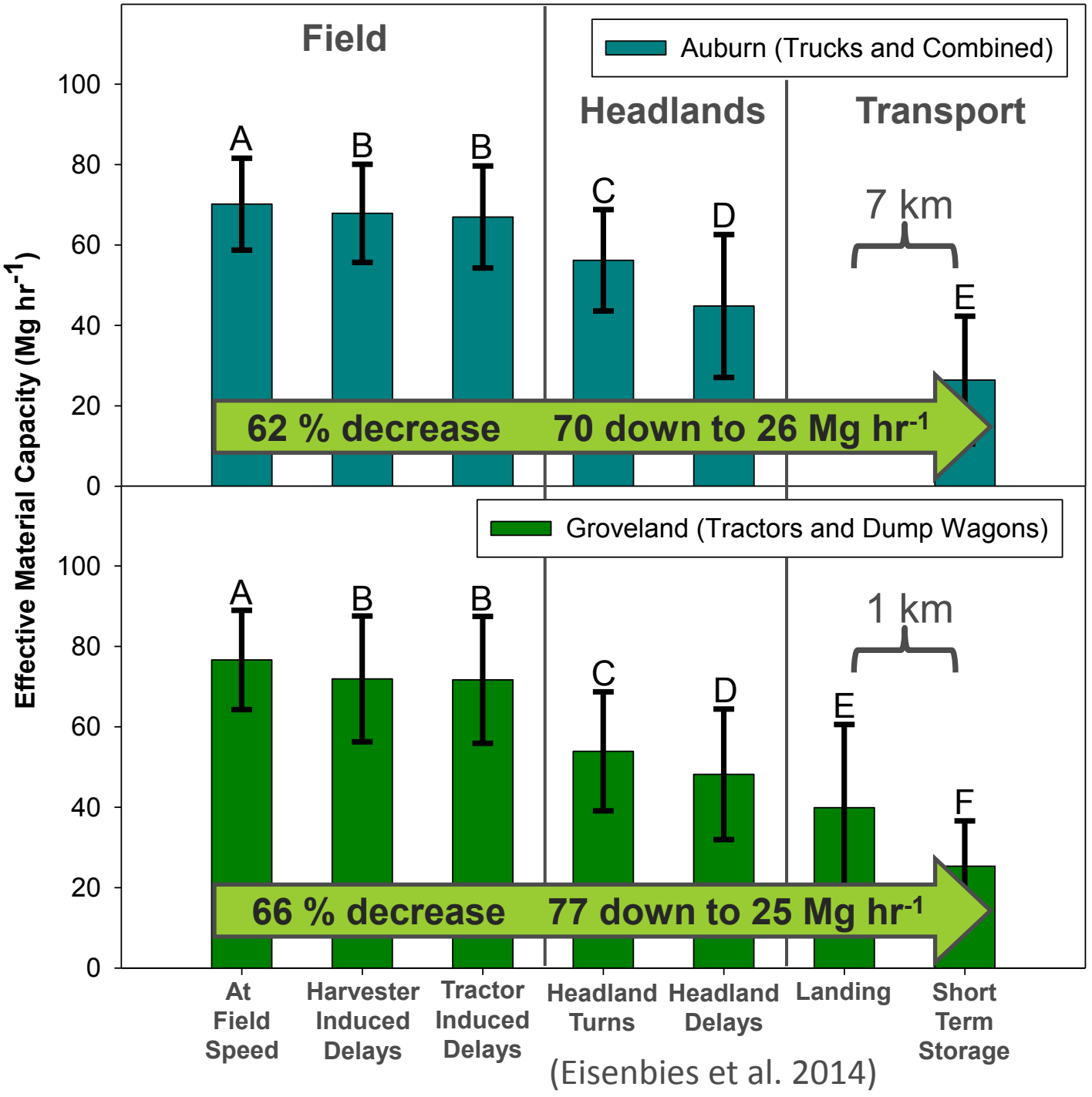

- A variety of collection vehicles were tried during previous harvesting operations
- The increased performance of the harvester has highlighted the need to improve the collection and delivery systems.

Project Overview

System Performance

"Out the Spout" to Storage

62-66% loss of efficiency



(Eisenbies et al. 2014)

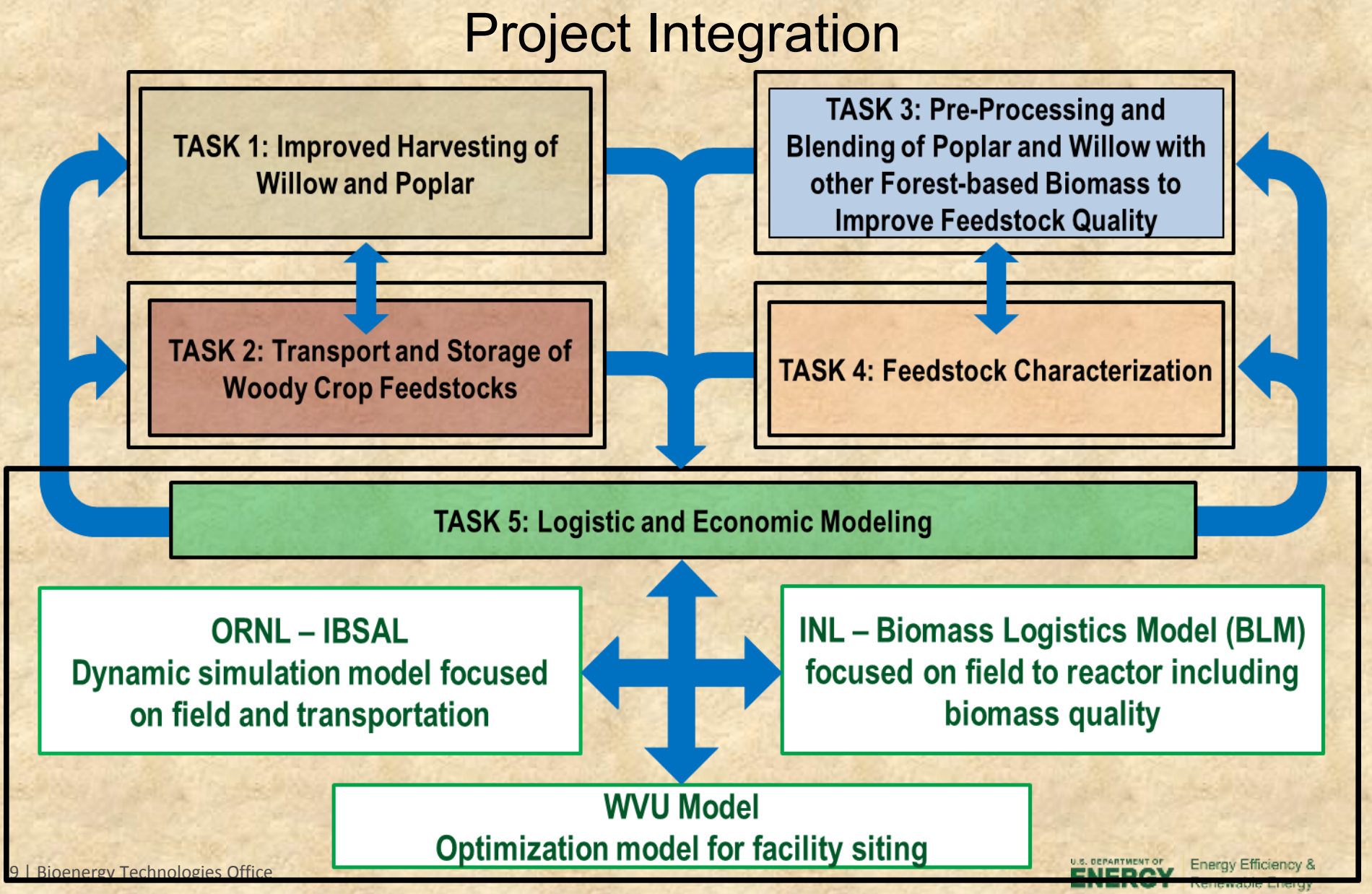
2 – Approach (Management)

- Project includes university (2), national labs (2), and commercial partners ranging in size from small to large

- **Management Approach**
  Iterative: Model Simulation/Optimization & Harvest Planning
  ➔Harvest Trials
  - Monthly conference calls/webinars and quarterly assessment of milestones using PMP
  - Task-specific conference calls/ webinars
  - Weekly internal meetings at ESF
  - Go/No-Go meeting midway through project

- **Structure**
  - Five integrated tasks with feedback and interaction among the tasks

2 – Approach (Technical) - Five Task Areas



2 – Approach (Technical) Five Task Areas

1. Improved Harvesting of Woody Crops (ESF, GWR)

- Improve efficiency and operability of New Holland harvester
- Improve data collection and integrate with machine performance
- Lower poplar/willow harvesting and logistics costs to meet $84/dry ton

2. Transport and Storage of SRWC feedstocks (ESF, GWR)

- Analysis of transportation of harvested willow and poplar biomass to lower cost of transition from field to end-user
- Analysis of storage options and conditions for willow and poplar to maintain or improve quality

3. Pre-Processing and Blending with other forest-based biomass to improve feedstock quality (ESF, GWR, INL)

- Evaluate pre-processing methods such as hot water extraction (HWE) to reduce feedstock variability, increase quality, shelf life, and value
- Identify combinations of processing conditions that balance energy consumption and cost with improved feedstock quality, consistency and throughput using the PDU at INL

2 – Approach (Technical) Five Task Areas

4. Feedstock Characterization throughout the supply chain (INL, ESF, GWR)

- Characterize feedstock quality along the supply chain using existing rapid-screening options (e.g. NIR) to monitor and evaluate the impact of supply chains operations on key biomass characteristics relative to biorefinery specifications
- Develop high-throughput screening systems that evaluate key feedstock characteristics and predict conversion process performance within the supply chain

5. Logistic and Economic Modeling (ORNL, INL, WVU)

- Develop advanced logistics and process simulation models to optimize planning and management of SRWC harvesting and logistics systems
- ORNL - IBSAL – simulate harvest and transport of harvest operations and provide optimizations for equipment for field-scale operations
- INL-BLM – Supply chain designs for delivered feedstocks and catalog of feedstock quality parameters through the supply chain
- WVU- Optimize siting and configurations including integration with other forest based biomass.

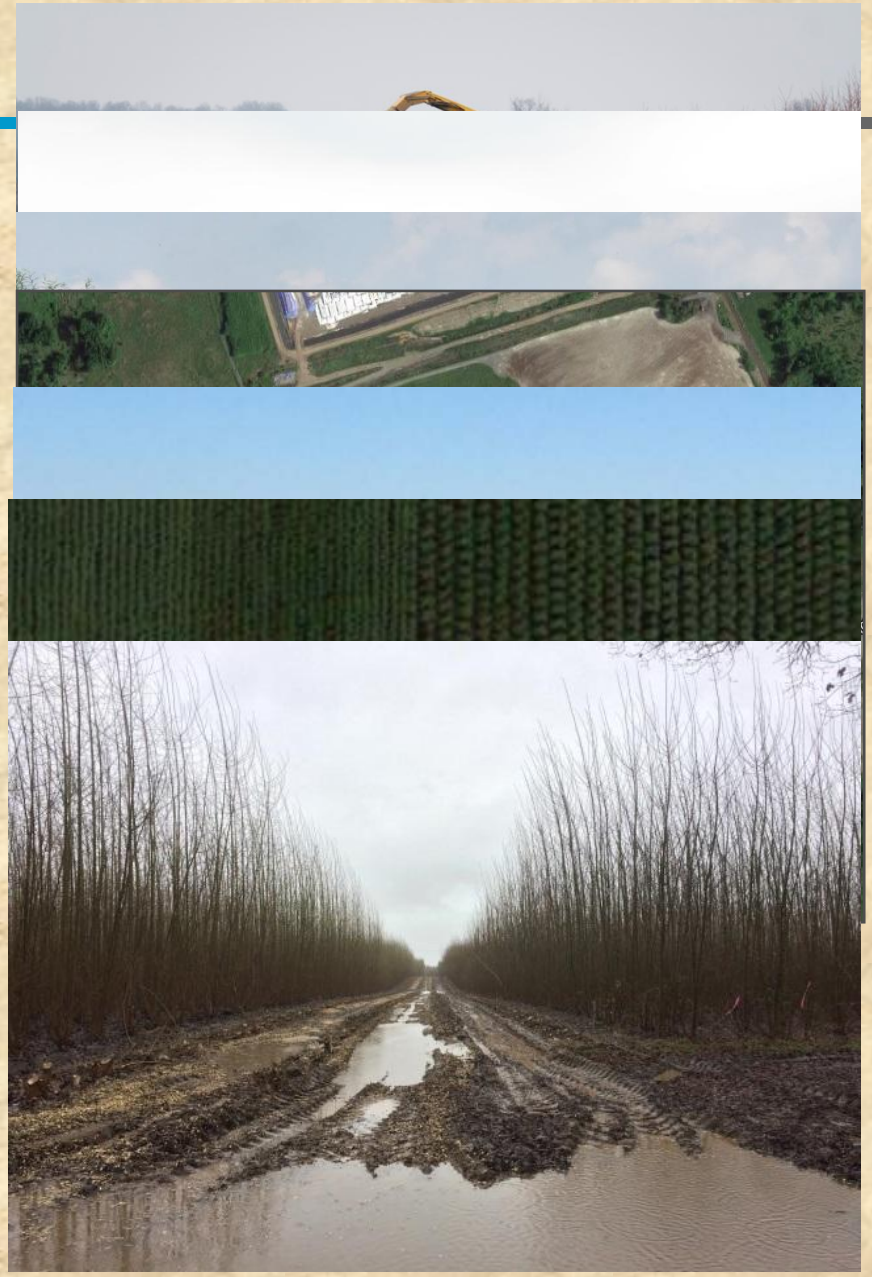
2 – Approach (Technical)

- **Critical Success Factors**
  - Achieve the $84 per dry ton costs to meet BETO goals
  - Improve system efficiency and expand harvesting window
  - Develop and implement system to affordably monitor quality (e.g. moisture content, ash content, sugars, lignin) in the field
  - Incorporate preprocessing technologies to maintain/improve quality
  - Optimize harvesting and logistics of woody crops through modeling

- **Challenges**
  - Diversity of field conditions with a variety of commercial partners
  - Coordination of multiple independent players along supply chain
    - Coordinating data collection with harvesting operations
    - Tracking feedstock quality through supply chain
  - Leaf-on harvesting, and harvesting in inclement weather
  - Uncertain end use markets in the future
  - Adapting NIR techniques for fresh biomass samples

B- Background

- **Opportunities and Challenges Across a Variety of Conditions**
  - Willow Legacy Plantings before 2010 (tight spacing)
  - New Planting Specifications after 20010 (wider spacing)
  - Commercial Growers
  - Phytoremediation Sites
  - Poplar Plantations
  - Different Densities
  - Variety of Ground Conditions
  - Seasonal Differences



3 - Technical Accomplishments/ Progress/ Results

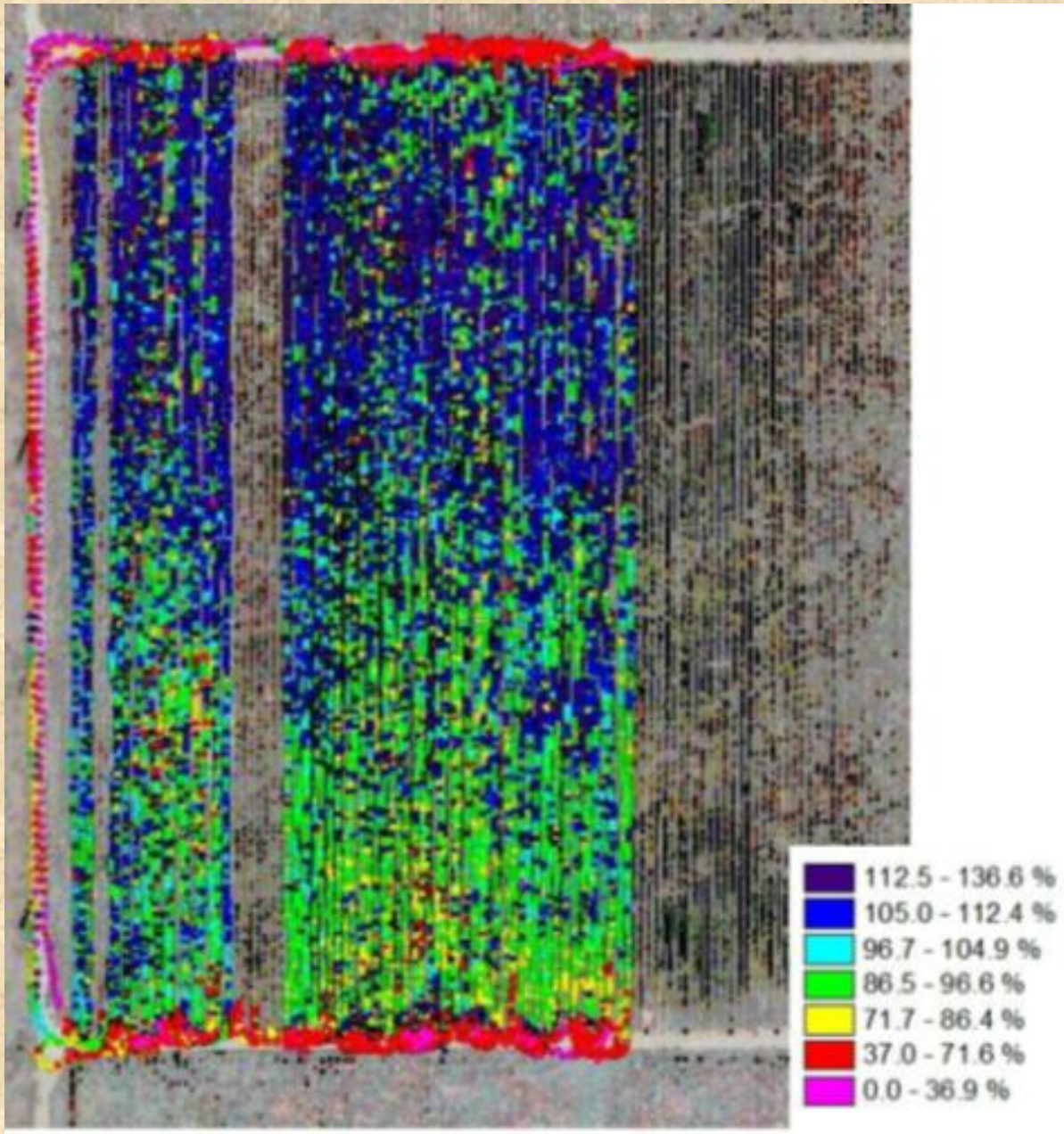
3 – Task 1- Improved Harvesting of Woody Crops

- **Progress**
  - Monitoring ~130 ha of willow and poplar harvesting
  - Modified and field tested new procedures to integrate data collection from on board computer (fuel consumption, engine load, ground speed, yield monitoring) with GPS and in field plant measurements
- **Tech Accomplishments**
  - Intelliview/PLM output to process data from on board computer
  - Methods to pair harvester performance with specific field and crop conditions (height, stem diameters, ground conditions, plant form)
  - Refined and implemented data collection for unharvested material
- **Milestones/Status**
  - Initial calibration of on board yield monitor
  - Expanding data collected to relate crop conditions to harvester performance
  - Developing methods to link GPS data with onboard machine performance is improving.
  - Height appears to be primary limiting plant characteristic
  - Two manuscripts in review and in press

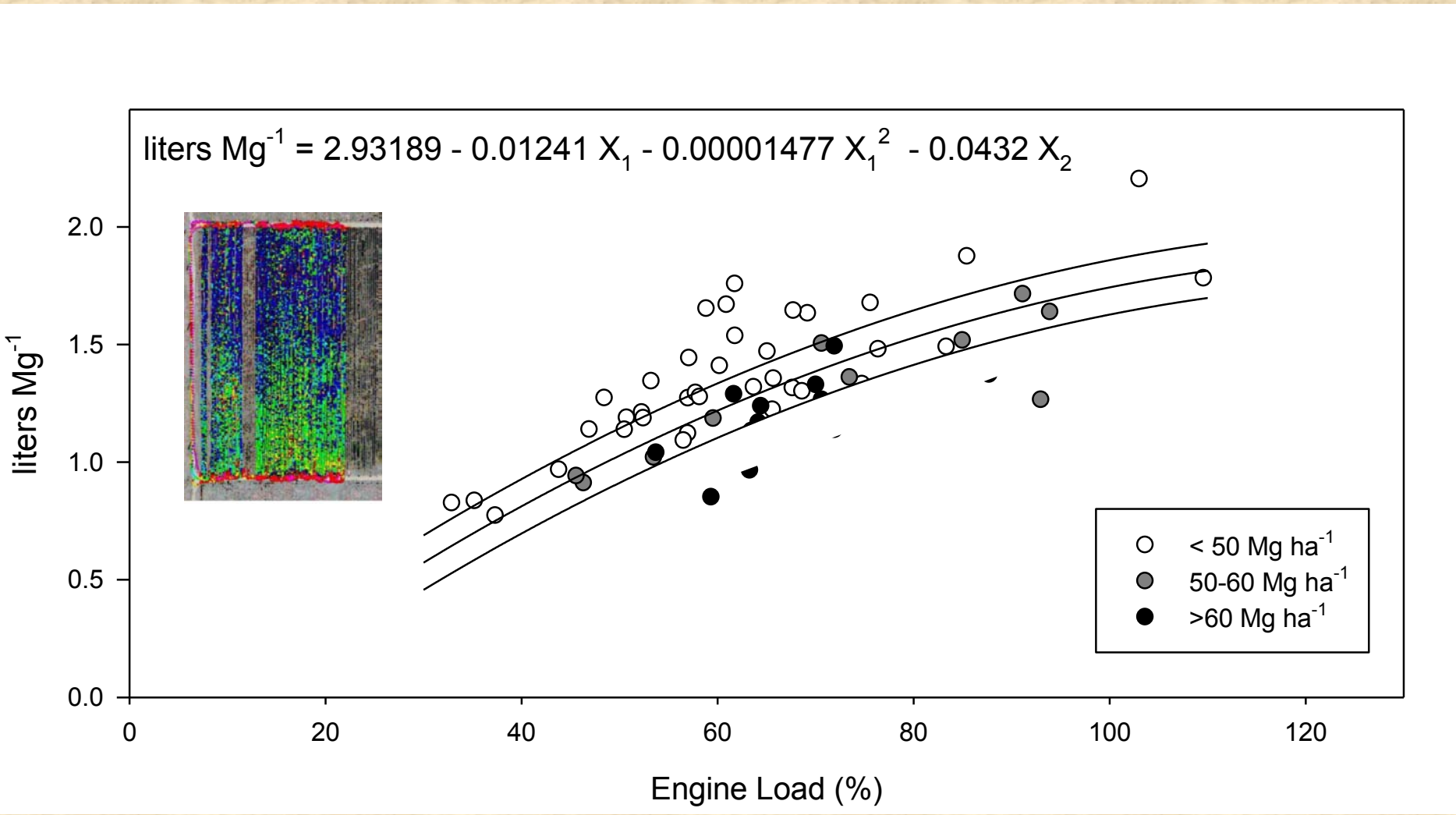
3 – Task 1- Improved Harvesting of Woody Crops

Engine load from harvest of hybrid poplar field in Pacific Northwest

Intelliview on board New Holland harvester

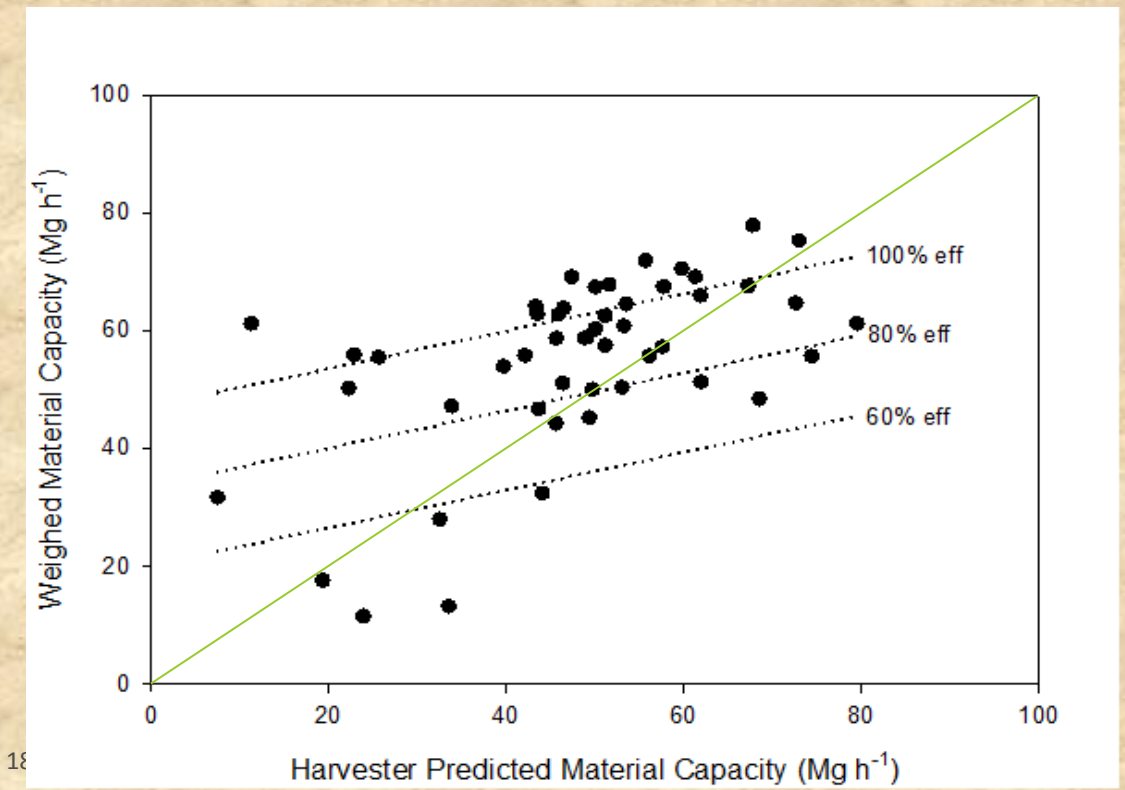


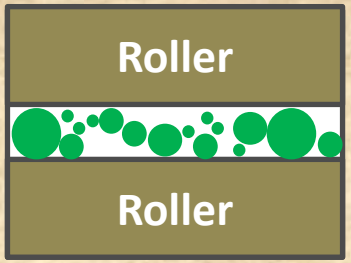
3 – Task 1- Improved Harvesting of Woody Crops

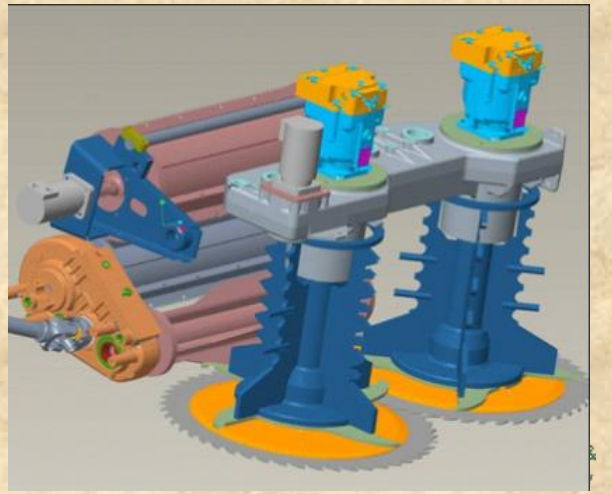


Task 1- Improved Harvesting of Woody Crops

- Evaluation of yield monitor (I-A)
  - Willow – R^2 0.70
  - Poplar – R^2 0.83 when we included in-field delay times
  - A propensity for the yield monitor to under-predict
  - More work is needed to refine yield estimates







3 – Task 2- Storage and Transport

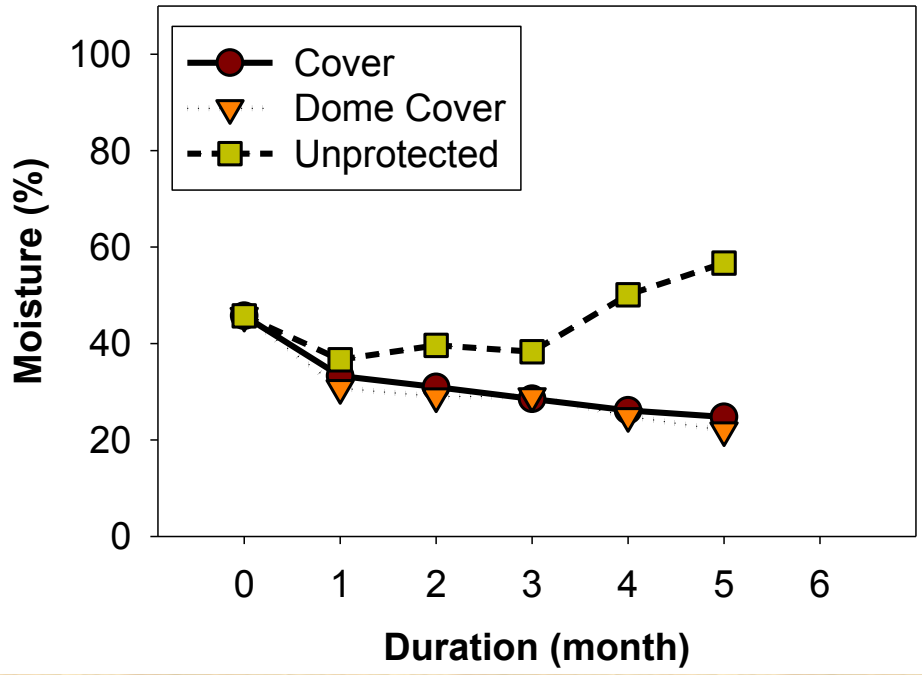
- **Progress**
  - Leaf-on willow pile studies monitored from June to December 2016
    - Factors included size, cover, passive ventilation
  - Leaf-off poplar pile study to start this month
  - >500 chip samples collected from various stages in the supply chain (fresh, short term storage, pile studies, and delivered)

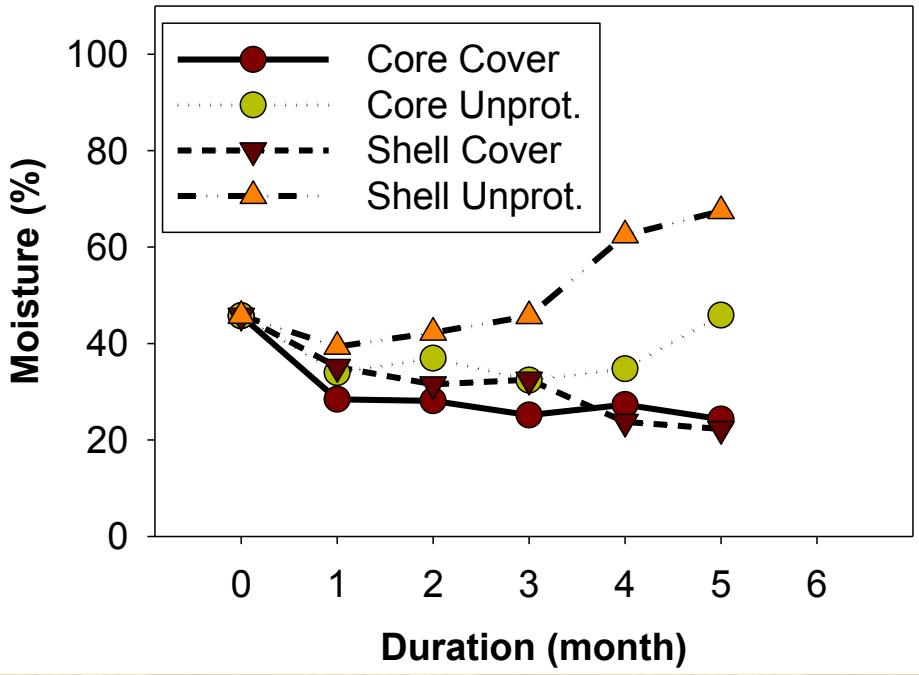
- **Tech Accomplishments**
  - Evaluating pile sizes and protection
  - Implementing bar code system so data can be linked to INL library

- **Milestones/Status**
  - Sampling protocols for collecting physical samples are in place; will be modified once NIR system is fully functional
  - Identified data gaps for modeling team and began addressing them
  - Published paper on initial storage trial of willow biomass crops
  - Collected data on loading and transportation of willow biomass from operational site

3 – Task 2- Storage and Transport

- **Leaf on pile study June to December 2016**





3 – Task 3- Preprocessing and Blending

- **Progress**
  - Willow HWE runs in 6 litre and 1.8 m^3 digesters
  - Truckloads of willow and poplar delivered to INL for use in PDU
- **Tech Accomplishments since 2015**
  - Initial bench pilot-scale trials with the hot water extraction (HWE) pretreatment process
    - Willow biomass responds in a similar fashion to reference hardwoods (sugar maple)
  - Further Refinements
    - particle size, temperatures, and residence time
- **Milestones/Status**
  - Bench-scale runs to develop time/temperature curves for willow are underway.
  - PDU trials with willow and poplar biomass are underway
  - A paper on the changes in quality due to HWE is in internal review
  - Paper on impact of mixtures of maple, willow, and HWE maple and willow chips for pellets is in preparation

3 – Task 3- Preprocessing and Blending – Hot Water Extraction™

- Utilizes a standard, paper industry pressure vessel
- is ***Clean Technology*** because it cooks wood chips in **water only**
- Incremental deconstruction of wood to capture valuable products

ABS Process™

CleanTech disassembly of woody biomass to capture value not currently realized

Extracted Woody Biomass

Water-based Extract Solution

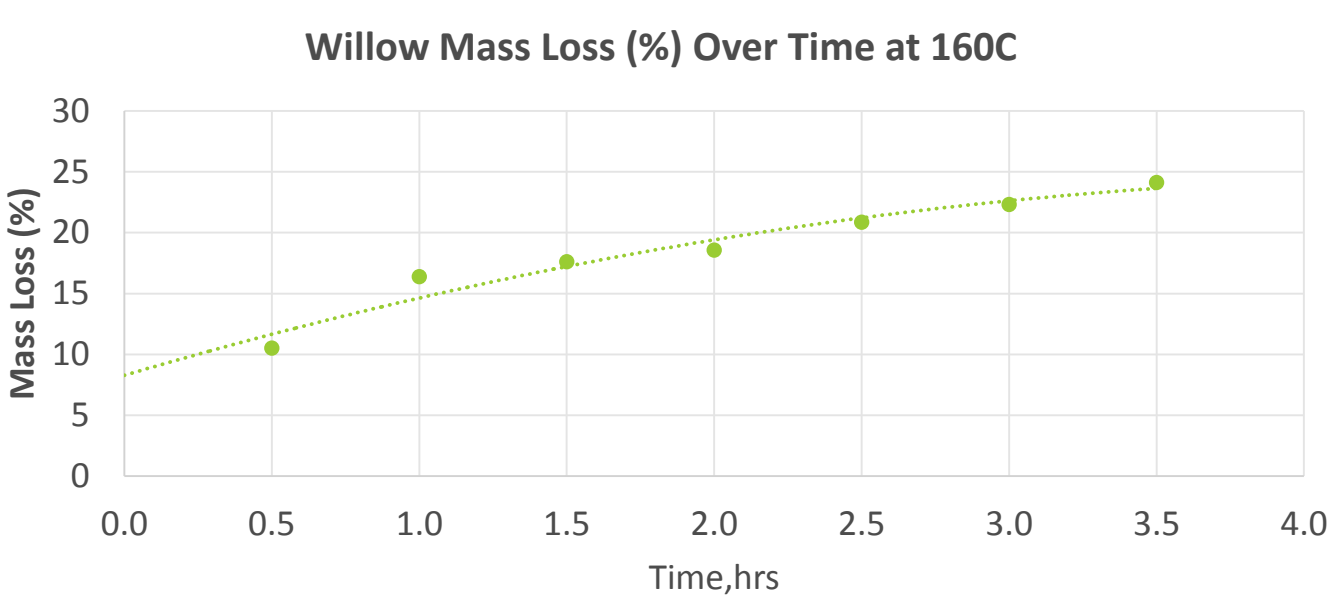
Pathway A

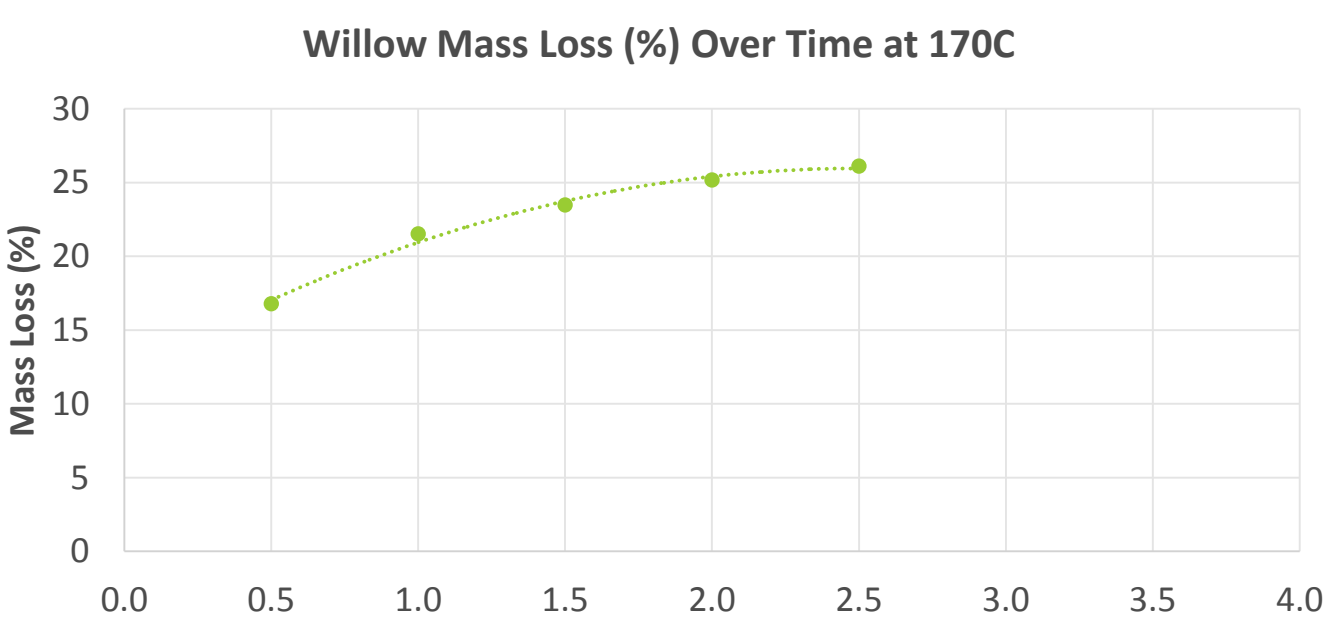
Hot Water Extraction™

Pathway B

Generating two product streams instead of just one

3 – Task 3- Preprocessing and Blending





- Changes in temperature and time impact mass loss of willow
- Bark in process has little impact on removal
- Issues related to particle size

3 – Task 4- Feedstock Characterization

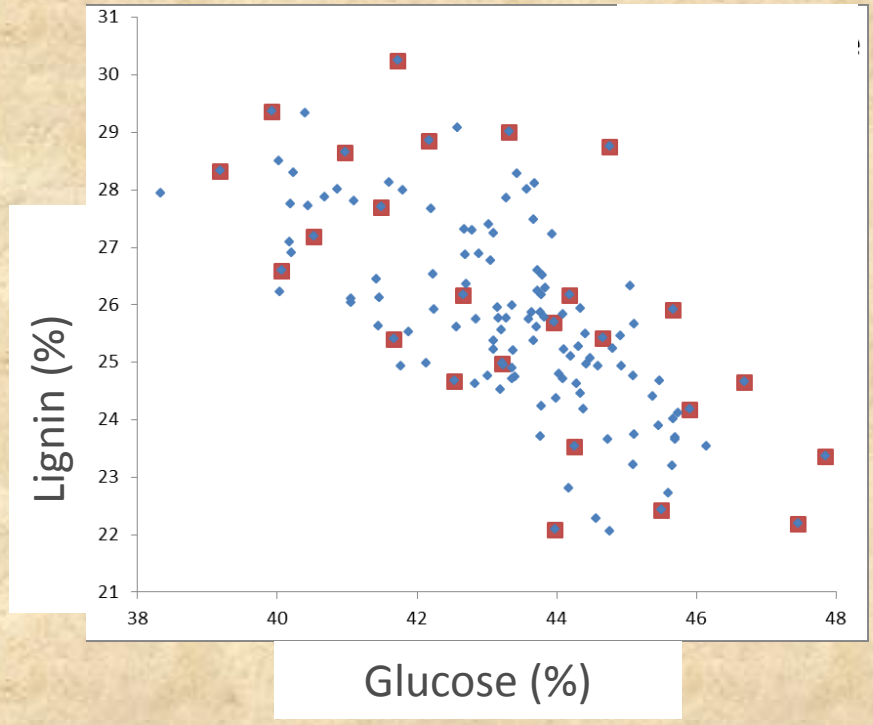
- **Progress**
  - Brimrose Luminar 5030 Handheld NIR was purchased
  - Over 200 willow samples scanned for composition and a subset of 25 samples have been sent to INL for wet chemistry to build NIR models
  - 32 poplar samples from 8 different clones were sent to INL for wet chemistry characterization to build NIR models

- **Tech Accomplishments since 2015**
  - Preliminary models developed for dried willow that give relative composition parameters
    - Screen for cellulose, hemicellulose, acid-insoluble lignin, and ash

- **Milestones/Status**
  - NIR based screening protocols are poised for deployment
  - NIR models will be updated based on wet chemistry and are will be expanded to include moisture content so fresh samples can be analyzed in the field

3 – Task 4- Feedstock Characterization

- **Progress**
  - Preliminary model developed for NIR for willow biomass based on previous wet chemistry work
    - Model under predicts hemicellulose content
  - Used model to screen about 200 samples of willow from range of genotypes and sites
  - Selected 25 samples to provide greatest range of characteristics for wet chemistry analysis at INL
  - 25 poplar samples from seven cultivars selected for wet chemistry analysis at INL



Attributes of 200 willow samples screened to select representative samples for wet chemistry at INL

3 – Task 5- Logistic and Economic Modeling

- **Progress**
  - ORNL – IBSAL is a dynamic simulation model based on field operations and transportation of biomass.
    - Regular meetings are occurring to synch field data with IBSAL inputs
  - INL- BLM model focused on field to reactor including preprocessing options with a focus on biomass quality
    - Two skeleton models have been developed for the chip/loose and densified formats of willow/hybrid poplar chip processing
    - Using data from PDU runs to improve models
  - WVU – Optimization model for siting facilities
    - Collecting data on (1) annual biomass feedstock availability data, (2) transportation network data, (3) construction limitation data, and (4) environmental impacts data.

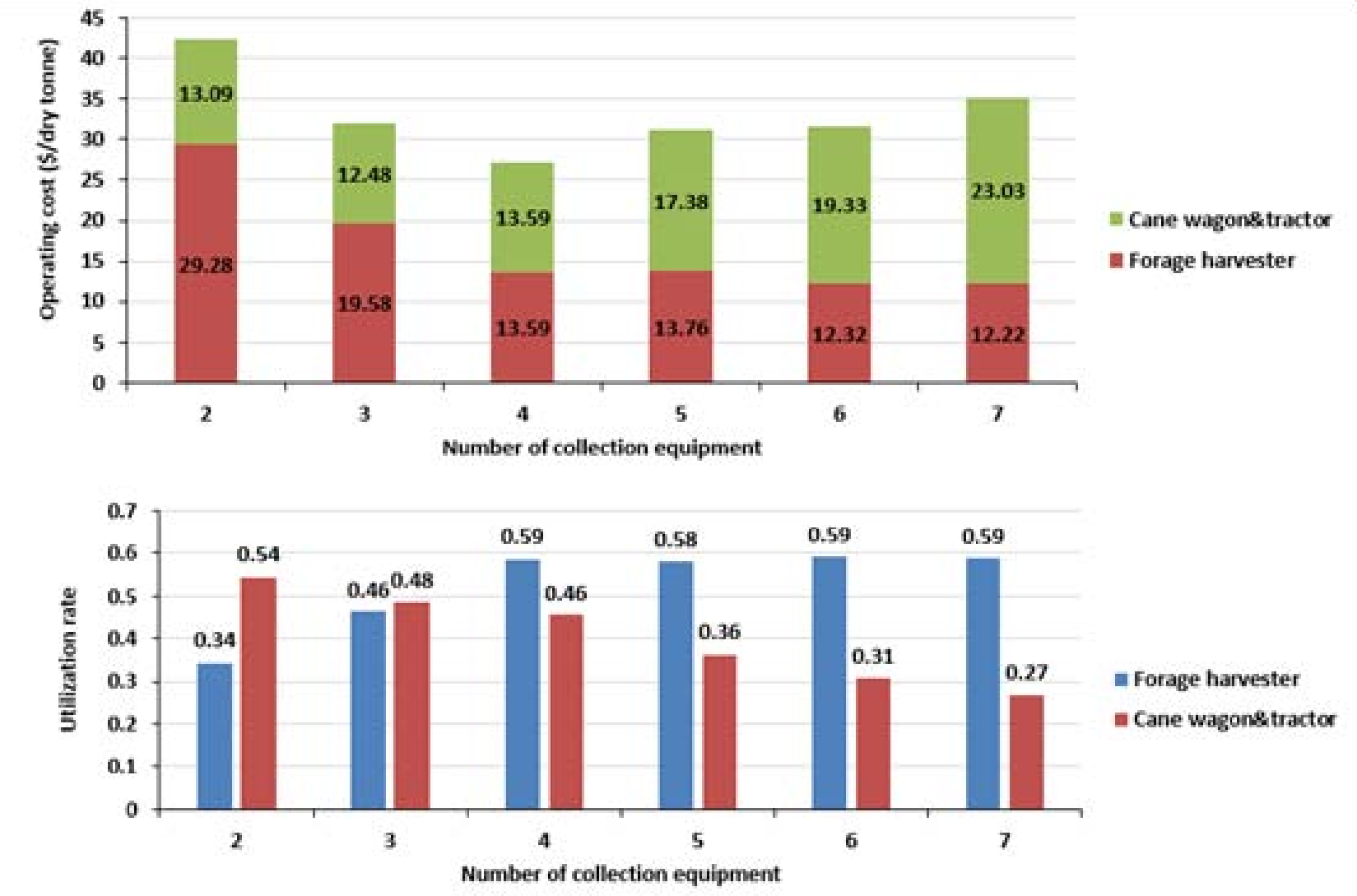
3 – Task 5- Logistic and Economic Modeling

- **Tech Accomplishments since 2015**
  - Baseline runs using IBSAL are being used to inform data acquisition priorities in the field
  - ORNL and ESF reviewing data collection and processing protocols
  - Developing inputs and outputs for different models to synchronize them and maximize benefits from analysis

- **Milestones/Status**
  - ORNL - IBSAL model being updated with new field information
  - INL – initial runs for BLM model underway
  - WVU – Initial framework and parameterization complete

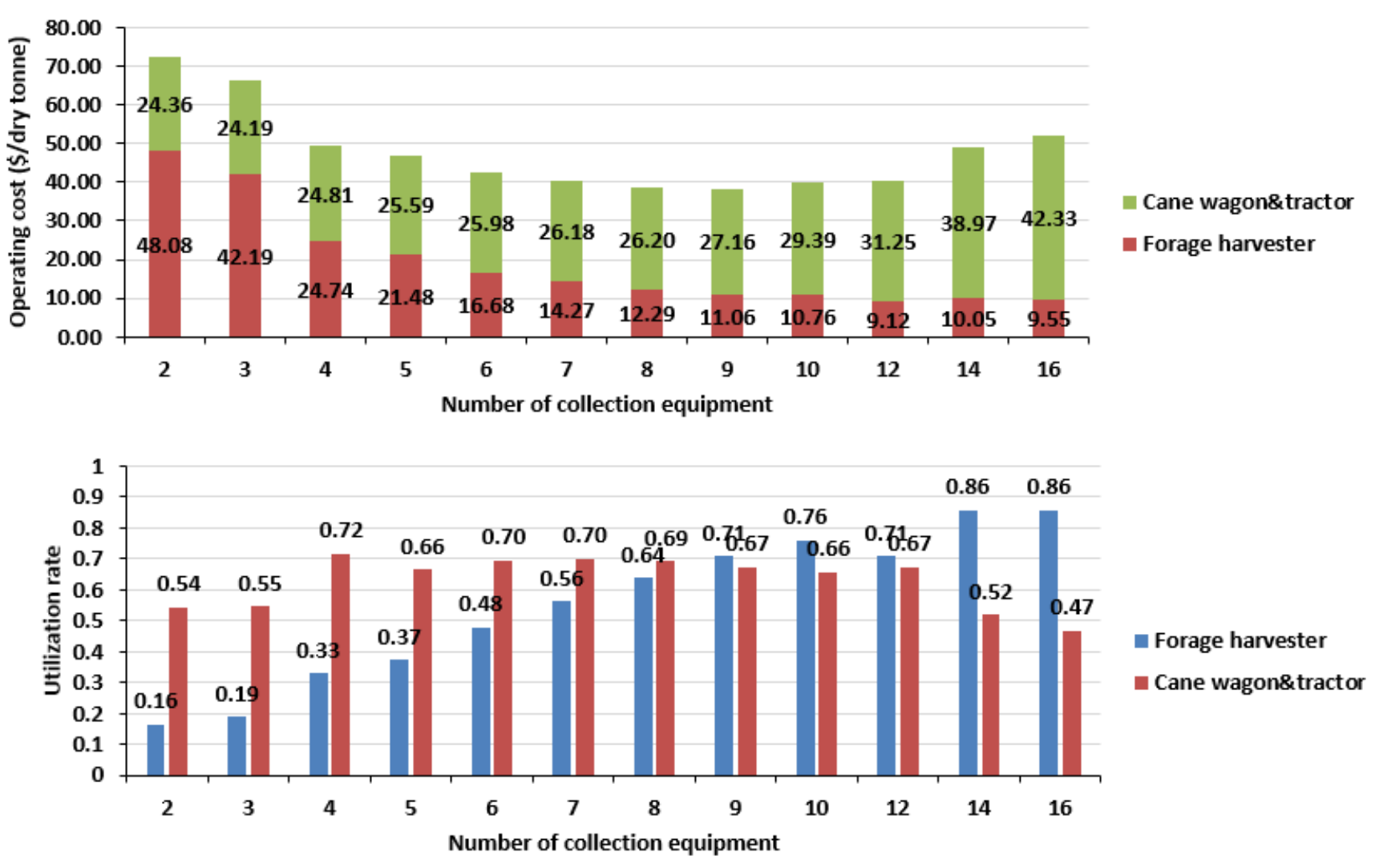
3 – Task 5- Logistic and Economic Modeling

- **Harvest of 10 ha willow field using baseline model in IBSAL**



3 – Task 5- Logistic and Economic Modeling

- **Harvest of 100 ha willow field using baseline model in IBSAL**



4– Relevance

- **BETO Platform Goals and Objectives (MYPP)**
  - Meet the $84/dry ton objectives by improving the efficiency one of the largest cost components of short rotation woody crops – harvesting and transportation
  - Addresses important facets of terrestrial feedstock supply and logistics in the MYPP
    - Biomass production, Harvest and collection, Storage, Transport and Handling, Preprocessing, Quality Characterization and Assessment

4– Relevance

- **Applications for the emerging bioenergy industry**
  - Working with private growers, end users and companies to optimize harvesting and logistics to meet their needs in two regions of the country.
  - Moving SRWC to commercialization by improving harvesting and logistics
    - Potential to create 54 – 63 jobs for every 10,000 of acres of willow grown for energy (Swenson 2010, 2014)
  - Ensure that biomass quality is maintained and/or identify quality challenges throughout supply chain to meet end user specifications and improve conversion efficiency
  - Supply samples and quality data to INL feedstock library so data is available for project developers

4– Relevance

- **Advance the state of technology**
  - Document and develop best practices for harvesting and establishment in conjunction with commercial growers and end users
  - Developing and implementing system to affordably monitor quality (e.g. moisture content, ash content) along the entire supply chain

5 - Future Work

- Task 1 Improved Harvesting of Woody Crops
  - Continue to monitor commercial willow and poplar harvests
  - Refine field data collection to synchronize with modeling needs
  - Publish BMPs for harvesting and logistics (e.g. harvester selection, collection vehicle optimization, field size and configurations, cultivar effects)

- Task 2 Transport and Storage
  - Implement poplar pile study
  - Conduct leaf off willow pile study
  - Refine field data collection to meet modeling needs
  - Publish BMPs for transport and storage of willow and poplar systems

- Task 3 Pre-Processing and Blending
  - Formulate recommendations for HWE preprocessing technology for fresh and stored willow feedstocks
  - Produce preprocessing pathways to meet different end user needs based on designs derived from PDU runs of willow and hybrid poplar

5 - Future Work

- Task 4 Feedstock Characterization
  - Develop and deploy rapid assessment protocols for fresh, stored, and transported feedstocks using NIR equipment
  - Monitor changes in quality along the supply chain
  - Expand INL Bioenergy Feedstock Library with array of willow and poplar samples

- Task 5 Logistic and Economic Modeling
  - Develop logistics configurations of biomass supply chains that include willow, hybrid poplar and other woody feedstocks delivered to the throat of the conversion facility
  - Provide recommendations based on modeling for in field harvesting operations and improve models based on field operations
  - Sensitivity analysis on input parameters to evaluate the impact on variability on model performance
  - Integrate different models being used to maximize benefits from analysis

Summary

- Principal goal is to lower the delivered cost of short rotation woody crops by optimizing a commercial-scale supply system:
  - $84 Dry Ton total cost to throat of conversion reactor
- Develop advanced logistics and process simulation models to optimize planning and management of the new and existing systems
  - Iterative process using models to inform harvests to generate improved harvest systems
- 130 ha of harvest have occurred with improved monitoring
- Storage studies underway looking at improved material handling
- HWE curves being developed as a treatment that improves and attenuate feedstock quality while providing marketable byproducts
- NIR methodology for rapid assessment to maintain feedstock quality throughout the supply chain

Extra Slides

Publications, Patents, Presentations, Awards, and Commercialization

Papers

- Volk, T.A., J.P. Heavey and M.H. Eisenbies. 2016. Advances in shrub-willow crops for bioenergy, renewable products, and environmental benefits. Food, Energy and Security. DOI - 10.1002/fes3.82
- Eisenbies, M., T.A. Volk and A. Patel. 2016. Changes in feedstock quality in willow chip piles created in winter from a commercial scale harvest. Biomass and Bioenergy 86:180-190.
- Vanbeveren, SPP, R Spinelli, M Eisenbies, J Schweier, B Mola-Yudego, N Maganotti, M Acuna, I Dimintriou, and R Ceulemans. *In Press.* Mechanized harvesting of short-rotation coppices. Renewable & Sustainable Energy Reviews.
- Eisenbies, MH, TA Volk, J Espinoza, C Gantz, R Shuren, B Stanton, and B Summers. *In Internal Review*. Silvicultural Factors Affecting Performance of a Single-Pass, Cut and Chip Harvest System on Commercial-Scale, Short-Rotation Hybrid Poplar Biomass Crops. Target journal Biomass and Bioenergy

Presentations

- T.A. Volk was interviewed for an article on willow production and harvesting for the SAF Monthly publication Forestry Source 21(5):6. http://www.nxtbook.com/nxtbooks/saf/forestrysource_201605/#/6)
- Volk, T.A., J. McAuliffe, C. Calkins, T. Eallonardo, L. Abrahamson, D. Daley, M. Eisenbies, J. Heavey, N. Sleight. Sustainable reuse remedy of former industrial land in central NY using shrub willows. Poplar and Willow National forum, Portland, OR. Arpil 11 – 13, 2016. (http://hardwoodbiofuels.org/wp-content/uploads/2016/04/2016-Forum-presentation_Volk.pdf)
- Eisenbies, M.H., J. Espinoza, R. Shuren, B. Stanton, B. Summers, A. Himes, J. Possellius. 2015. Harvesting short rotation hybrid poplar using a New Holland Forage Harvester and SRC Woody Crop Header. USDA AFRI annual meeting. Sept.8-10. Seattle, WA.
- Eisenbies, MH,TA Volk, O Therasme. 2016. Storage, Processing and Quality of Willow Chips. NewBio Annual Meeting. Penn State University, PA., July 26-28, 2016

Responses to Previous Reviewers' Comments

3 – Task 4- Feedstock Characterization