2021 Project Peer Review

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

March 9, 2021

Feedstock Technology Program

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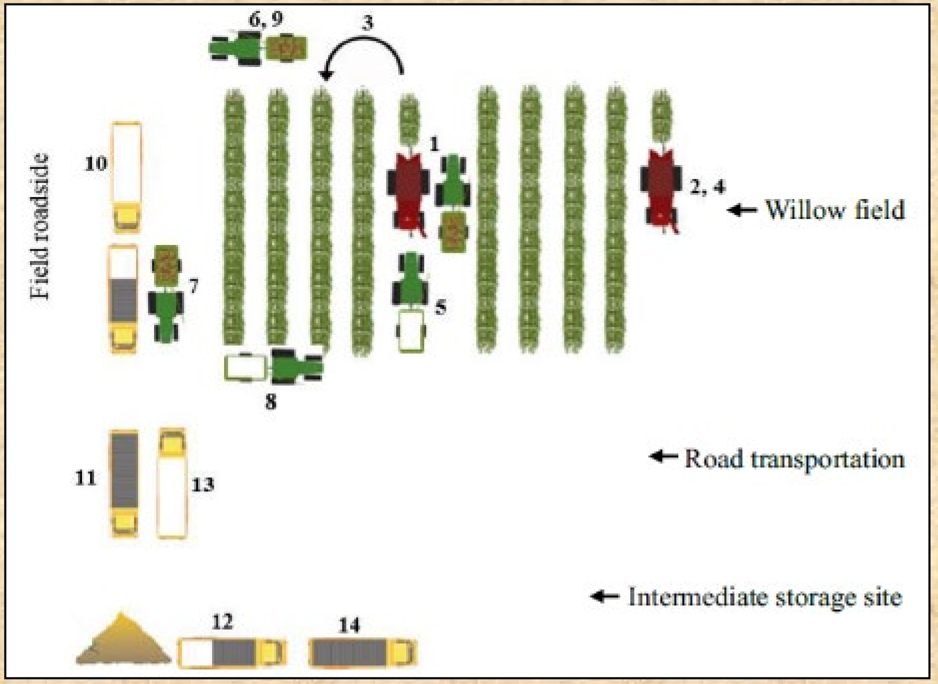
Project Overview

- Harvesting and transportation makes up 40 – 60% of the delivered cost of SRWC (Frank et al. 2018) and are an important source of GHG emissions (Yang et al. 2020)
- Harvestings systems are not well developed - throughput decreases up to 65% from harvester to short term storage (Eisenbies et al. 2014)
- Changes in biomass quality and impacts of pretreatment techniques are not well understood
- Most of the available data on SRWC harvesting operations is based on trials in small, research plots
- Available information on harvesting limited to narrow set of ideal ground and weather conditions



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Goal Statement

- Goal: Lower the delivered cost of short rotation woody crops (SRWC) (hybrid poplar in the northwest and willow in the northeast) by optimizing harvesting and logistics supply systems while maintaining or improving biomass quality along the supply chain

1 - Management - Project Partners and Collaborators

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

GreenWood Resources
A Resource That Lasts Forever

INL
Idaho National Laboratory

Oak Ridge
National Laboratory

West Virginia University

Applied Biorefinery Sciences

celtic energy farm

New Holland Agriculture

ReEnergy Holdings LLC

nyserda
Energy. Innovation. Solutions.

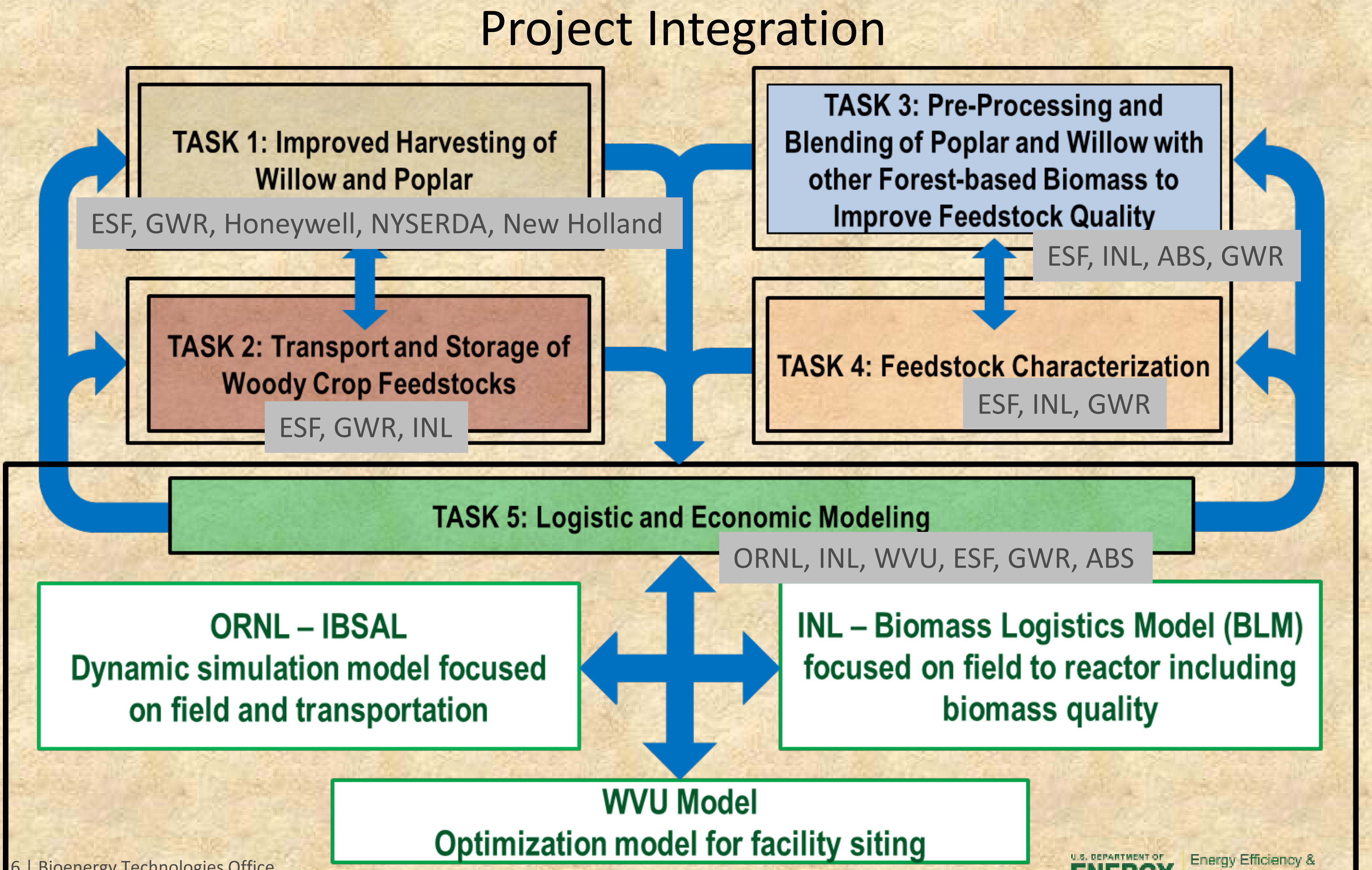
USDA Natural Resources Conservation Service

Honeywell

1 - Management - Project Partners and Roles

Organization	Main Responsibility	Lead Individual
State University of NY College of Environmental Science and Forestry (ESF)	Project management, willow and poplar trial data collection and analysis, storage trials, NIR model development	Timothy Volk
Applied Biorefinery Sciences (ABS)	Develop and test hot water extraction system	Thomas Amidon
GreenWood Resources (GWR)	Management of poplar crop and harvesting trials, poplar trial data collection	Brian Stanton
Idaho National Lab (INL)	Willow and poplar PDU preprocessing trials, BLM model, wet chemistry analysis	Rachel Emmerson
Oak Ridge National Lab (ORNL)	IBSAL model development and runs	Erin Webb
University of West Virginia (UWV)	Spatial citing model development and runs	Jingxin Wang
Industry Partner Collaborators: Celtic Energy Farms, Honeywell International, New Holland Agriculture, ReEnergy Holdings		

1 – Management - Five Integrated Tasks



1 – Management

- **Management Approach**
  Iterative interaction between in data collection and modeling task groups:
  - Harvesting trials and data collection ➔ Preprocessing and Storage Model ➔ Simulation/Optimization ➔ Harvesting trials and data
- **Meetings**
  - Monthly teleconference meeting for entire team
  - Monthly teleconference meeting for modeling partners
  - Task-specific conference calls as needed to address concerns or problems
  - Go/No-Go meeting completed March 2017
- **Communications**
  - Team wide quarterly assessment of milestones using PMP
  - On line data sharing platform
- **Final report submitted in Dec 2020**

2 – Management – Risks and Mitigation Strategies

- Coordination among tasks
  - Added quarterly specific modeling and other task meetings
- Field conditions, weather, equipment failures
  - Earlier preplanning harvests
  - Built in additional flex time
  - Operational realism
- Various objectives among growers
  - Improved coordination with partners using new tools (i.e. UAV)
  - Accelerated information sharing with partners to meet their objectives
- Changing and uncertain end use markets
  - Be flexible on timing and locations
- Samples lost during shipping
  - Screened hundreds of samples so replacement possible
- Unplanned and abrupt personnel changes
  - Reallocated work and modified timeline

Harvesting poplar SRWC and scouting willow crops with UAV

2 – Approach – Advance State of the Art

- Built on previous DOE and NYSERDA projects that developed SRWC harvesting system
- Cost and quality were key metrics
- Commercial scale and operational relevance
- Addressed BETO Milestones and Barriers
  - BETO milestone (20FS24) to develop feedstock supply systems
  - Target: $84/dry ton cost to throat of conversion reactor (harvesting costs < $54/dry ton)
  - Barriers : Sustainable Harvesting (Ft-D), Availability of Quality Feedstock (Qt-A), Feedstock Availability and Cost (Ft-A)

Unloading willow chips at temporary storage and wood chip pile at ReEnergy

2 – Approach - Advance State of the Art

- Focused on large-scale harvesting trials over a wide range of field and SRWC crop conditions to improve system and large-scale supply system models
- Majority of harvesting and logistics activities were based on operators' decisions, with a few select trials designed to collect specific information for other tasks
  - Coordinate with growers, haulers, and end users for sampling
- Made use of three models with different strengths to address specific questions related to scale up and uncertainty taking advantage of stochastic data sets created by other tasks

Harvesting poplar and wood piles at ReEnergy

3 – Impact - Information Sharing

- Information dissemination
  - peer reviewed publications
  - series of short technical summaries and information sheets
  - in-field demonstrations
  - webinars
  - sharing biomass samples ranging from a few kg to truck loads of material
- FB 130 Coppice header available through network of New Holland dealers
- Sharing results with growers, operators and end users and learning from them
  - Sugar cane wagon introduced by Celtic Energy Farms was a significant improvement

Harvesting field day and screen shot from Farm SIM game with New Holland coppice header information embedded.

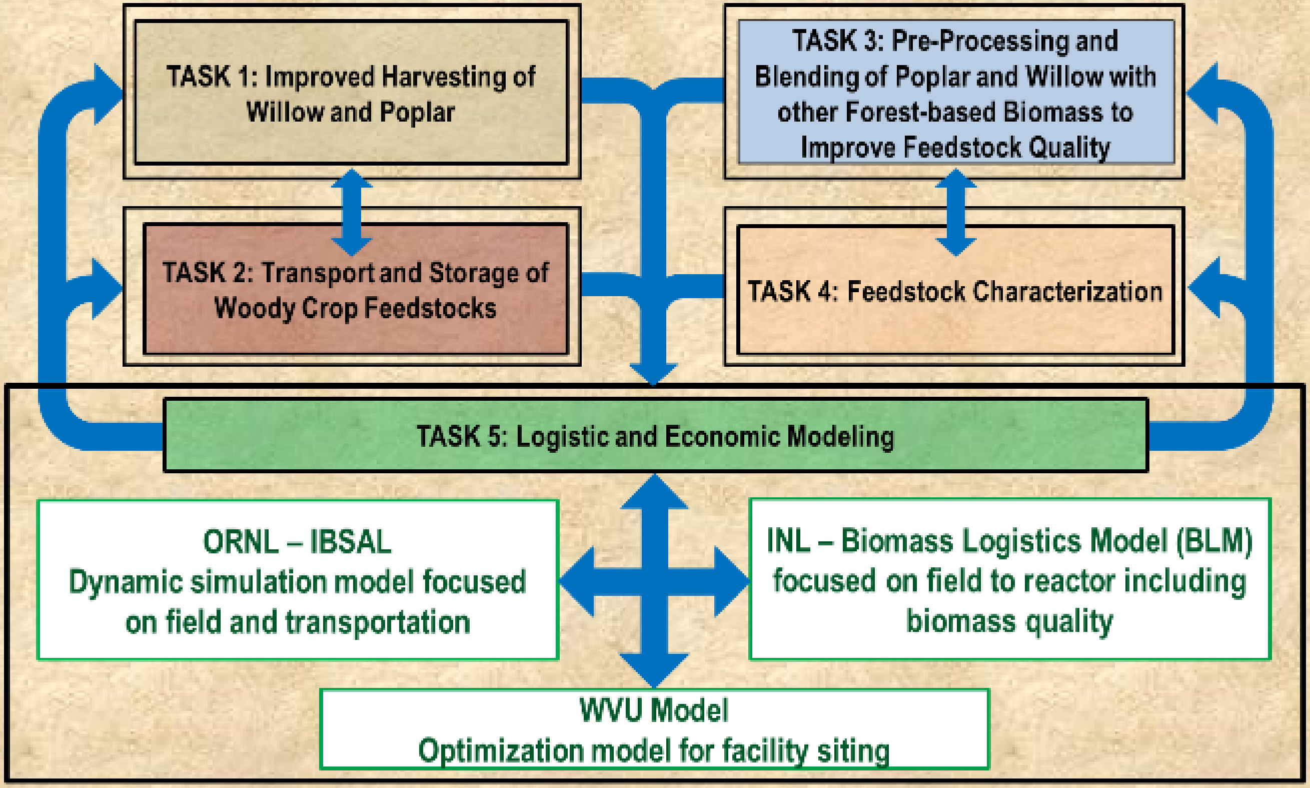
3 – Impact – Interested Parties and Partners

- Worked closely with diverse groups to advance SRWC systems and change misperceptions about willow biomass crops
  - willow and poplar growers and landowners
  - equipment manufacturers and dealers
  - current and potential biomass end users
  - project developers interested in using poplar and willow
  - USDA NRCS and FSA - staff training and protocols development
  - policy makers

End users initially were skeptical and piled willow separately from forest residues but after trials incorporated material into regular handling system highlighted benefits

4 – Progress and Outcomes

- Highlights for each of the five task areas
- Progress
  - Main thrusts
- Outcomes
  - Main achievements
- Milestones
  - Publications
  - Presentations



4 – Task 1- Improved Harvesting of Woody Crops (ESF, GWR, Honeywell, NYSERDA)

- **Progress**
  - Monitoring harvesting operations on 740 ac of willow and poplar
  - 790 commercial wagon loads
  - Combined with legacy work to evaluate over 1,000 loads for an operationally relevant expanded harvesting window
- **Outcomes**
  - Regression models for harvester performance (e.g. throughput and fuel consumption) for different crop and ground conditions
  - **All information used to inform modeling task (Task 5)**
- **Milestones/Status**
  - 8 refereed journals-dissertations-thesis
  - 12 professional presentations
  - Other data summarized in final report

Leaf Off
Dry Weather

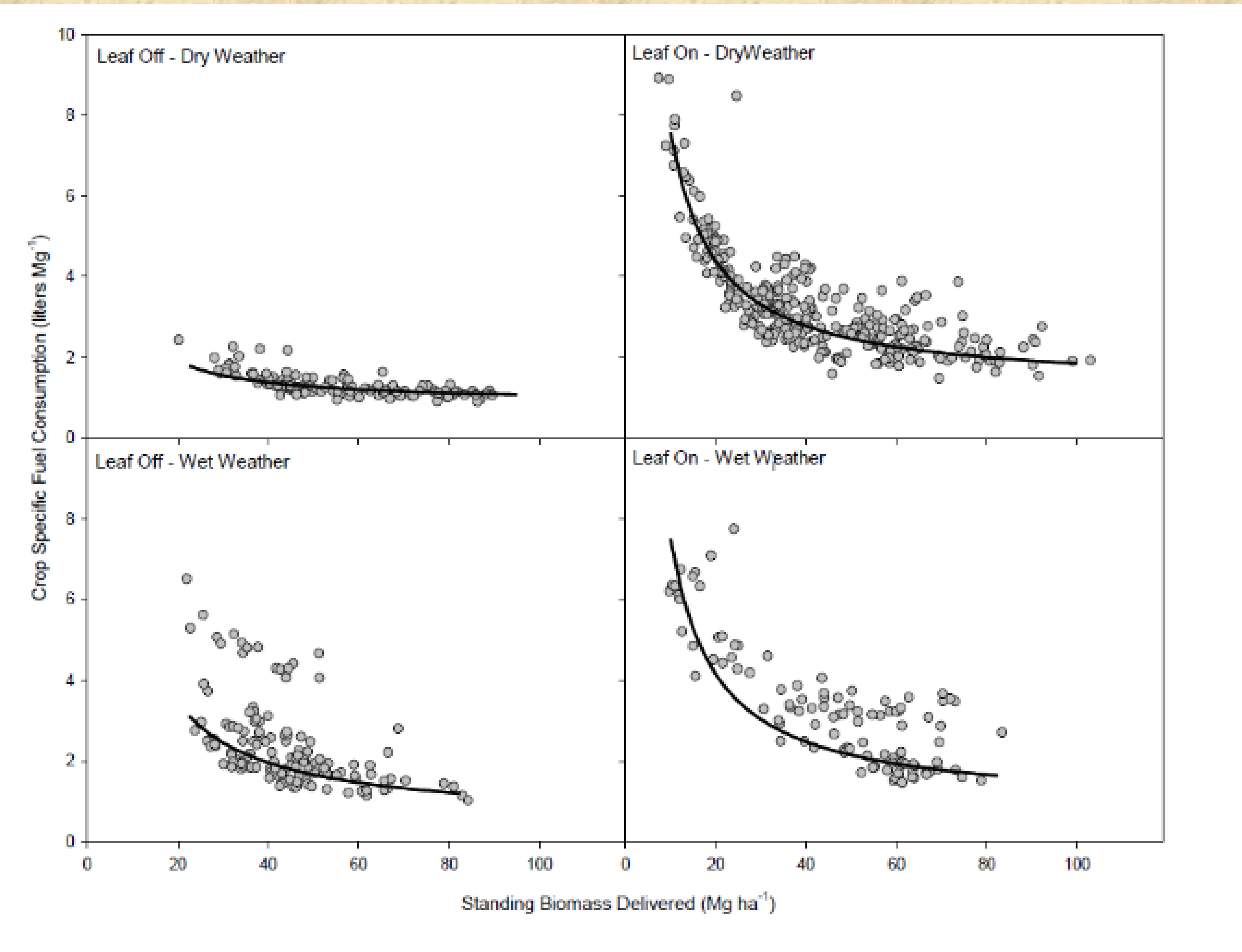
Leaf On
Dry Weather

Leaf Off
Wet Weather

Leaf On
Wet Weather

Harvesting willow and poplar crops at different times of the year and in varying conditions.

4 – Task 1- Improved Harvesting of Woody Crops (ESF, GWR, Honeywell, NYSERDA)



Crop specific fuel consumption in willow biomass crops in leaf on and leaf off conditions and under wet and dry crop conditions (Eisenbies et al. 2020)

4 – Task 2- Storage and Transport (ESF, GWR, ORNL)

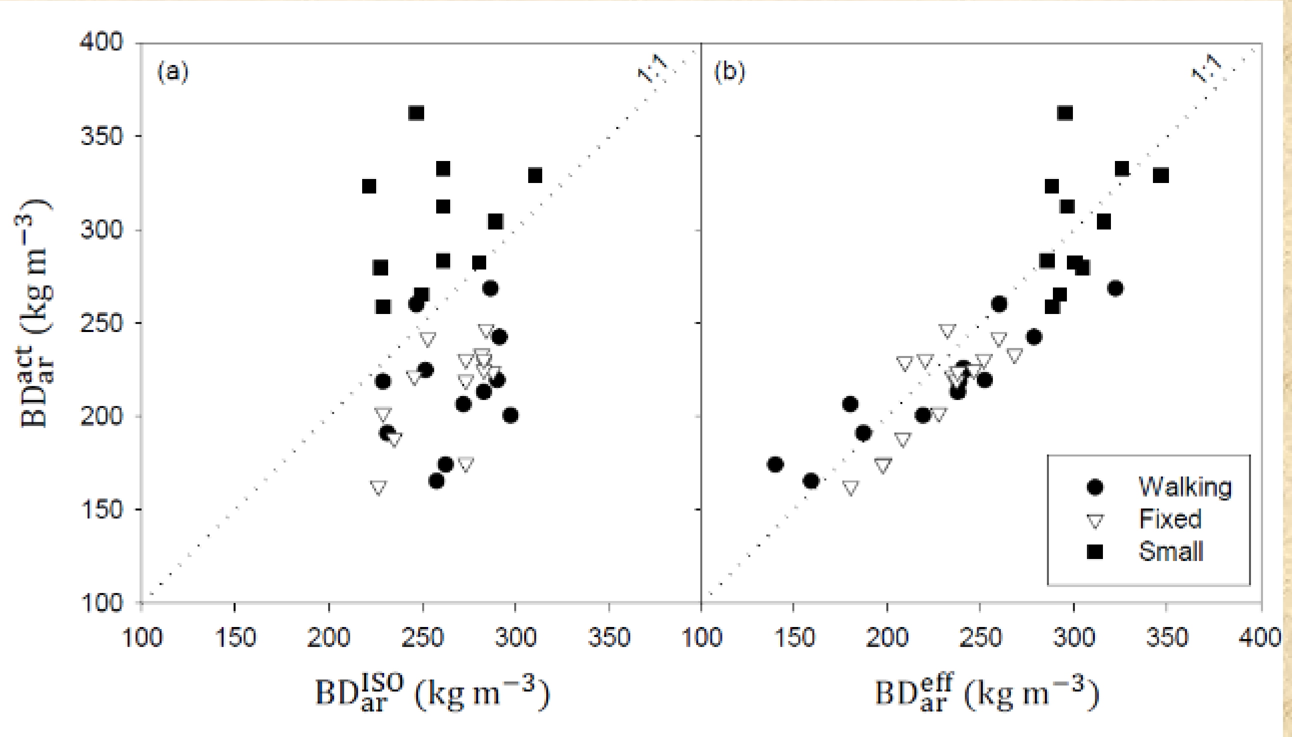
- **Progress**
  - Bulk density studies
  - Storage studies
  - Preprocessing Storage Studies
- **Outcomes**
  - Dry matter loss models
  - Seasonal and duration recommendations
  - Protection/cover effects on composition and quality
  - Preprocessing effects on composition and quality
  - Vehicle speed on trails
  - Material losses at landings
  - **All information used to inform the modeling task (Task 5)**

- **Milestones/Status**
  - 5 refereed journals-dissertations-thesis
  - 3 professional presentations
  - Other data in final report

Willow harvest with focus on logistics of storage locations and field conditions

4 – Task 2- Storage and Transport (ESF, GWR, ORNL)

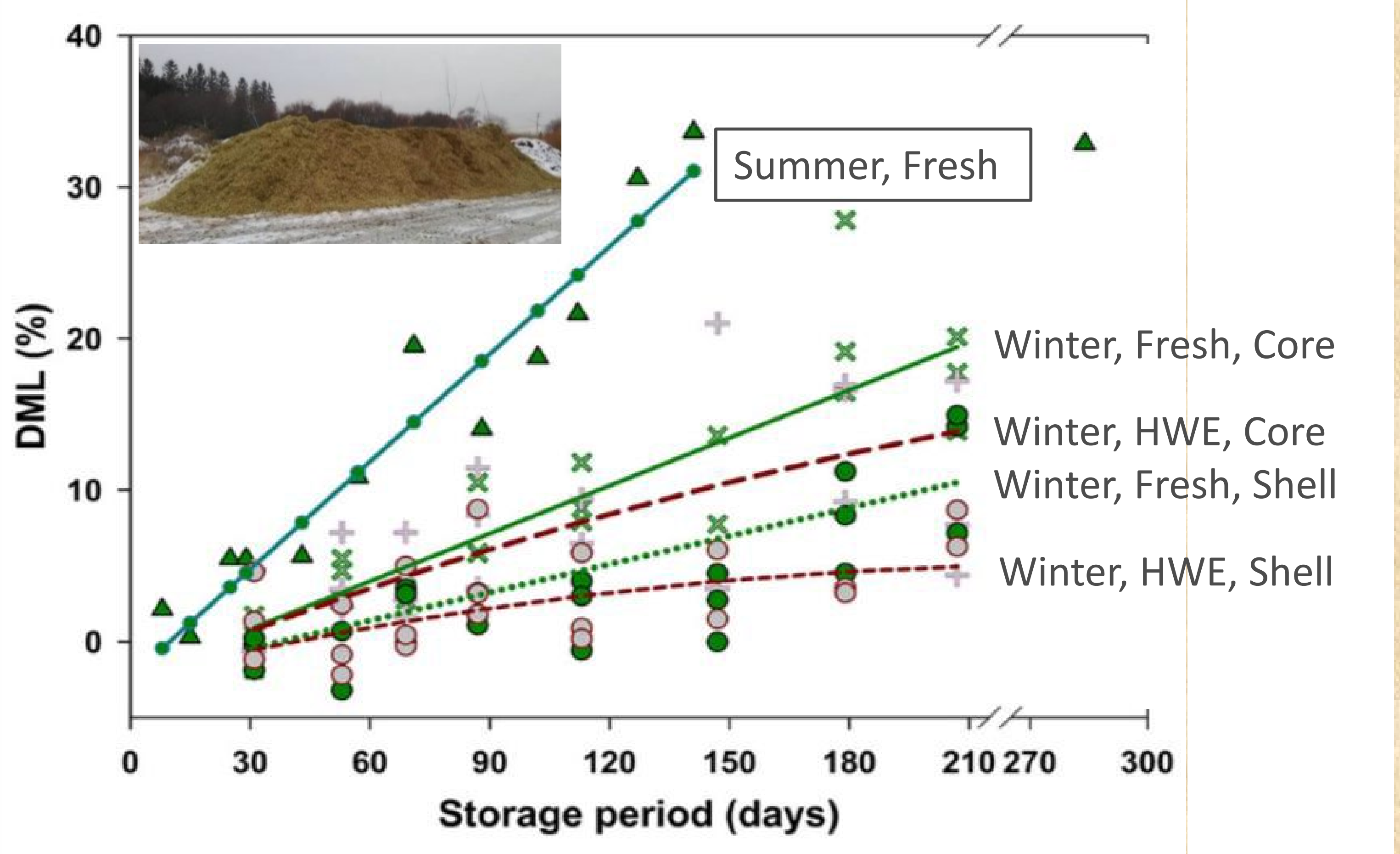
Bulk density trial example



Relationship between as-received bulk densities measured directly from the three collection vehicles to standard bulk densities (ISO 17828:2015) and effective bulk density (ratio of weight to the fixed dump body volume). (Eisenbies et al. 2019).

4 – Task 2- Storage and Transport (ESF, GWR, ORNL)

Willow dry matter loss during storage for hot water extraction (HWE) pretreatment and season (Therasme et al. 2020)



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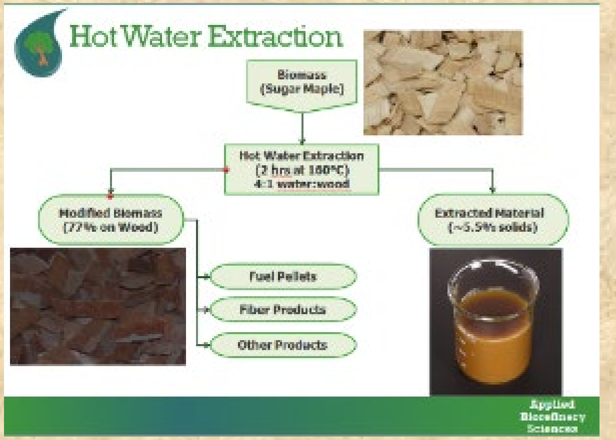
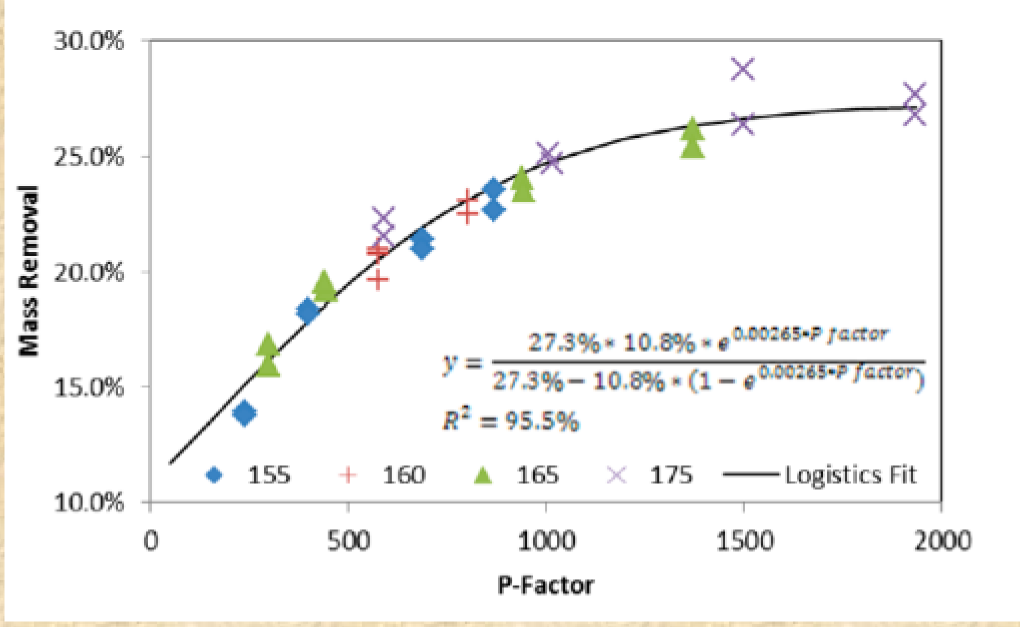
4 – Task 3- Preprocessing and Blending (INL, ABS, ESF, GWR)

- **Progress**
  - Developed hot water extraction operational parameters
  - Blending studies
  - Other pretreatments (air classification grinding, drying)
- **Outcomes**
  - Proof of concept for several pretreatments and blending strategies
  - Energy and cost studies for pretreatments were completed
  - **All information used to inform the modeling task (Task 5)**
- **Milestones/Status**
  - 5 refereed journals-dissertations-thesis
  - 4 professional presentations
  - Other data summarized in final report



4 – Task 3- Preprocessing and Blending (ESF, ABS, GWR, INL)

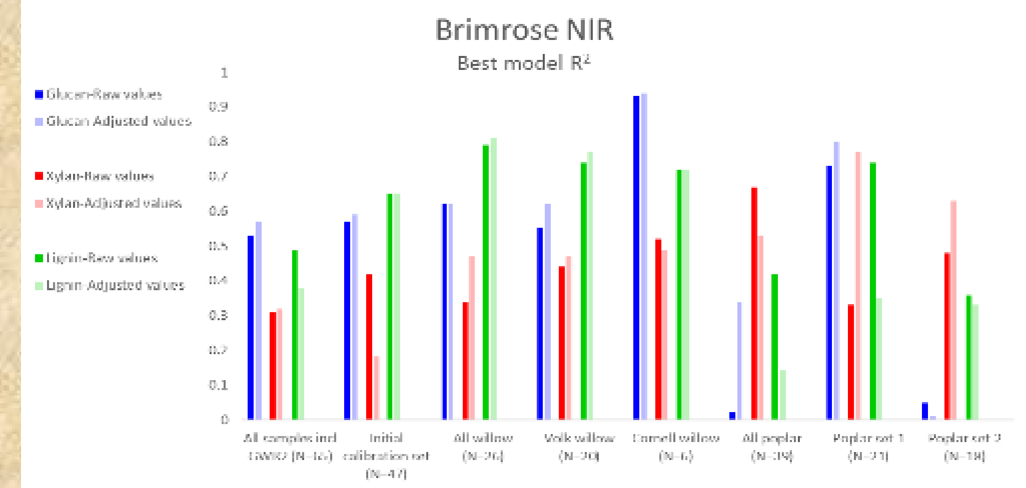
- Hot water extraction (HWE)
- PDU Processing Strategies
- Variables
  - Crop: Poplar, Willow
  - Moisture Content: 10%, 20%
  - Air Classification: No, Yes
  - Grinding: 0.75”, 0.25”
  - Densification
- Poplar: 661 to 2,097 kWh/dry ton
- Willow: 758 to 958 kWh/dry ton
- Drying is the most energy intensive and expensive operation
- Air classification is low energy and improves quality

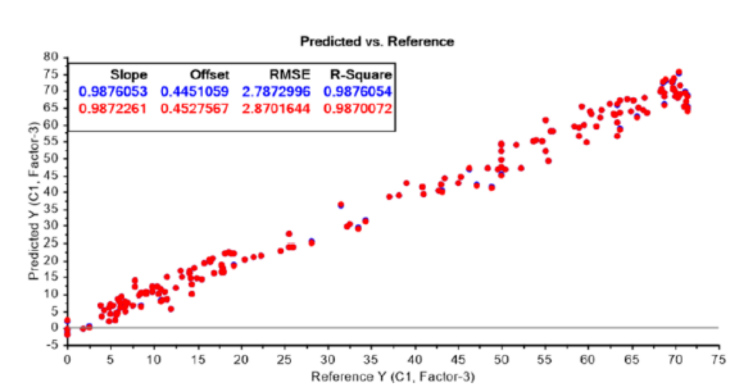


Mass removal from willow under different HWE conditions (processing time and temperatures, P-factor) (Wood et al. 2020)

3 – Task 4- Feedstock Characterization (ESF, INL, GWR)

- **Progress**
  - 11 NIR Model thrusts
  - 4 TGA Model thrusts
- **Outputs**
  - Models developed for Willow and Poplar using 65 samples with wet chemistry data
- **Milestones/Status**
  - Models for
    - Glucan 30-42% (best $R^2 \approx 0.60$)
    - Xylan 8-15% (best $R^2 \approx 0.40$)
    - Lignin 22-28% (best $R^2 \approx 0.75$)
    - Moisture content ($R^2 = 0.98$; RMSEVC below 3%)
  - Low RMSE (<2%) for all components
  - In addition to wet chemistry samples, almost 1,500 samples sent to bioenergy library





Top: Comparison of best model R^2 for glucan, xylan, and lignin using NIR
Bottom: NIR Moisture Model

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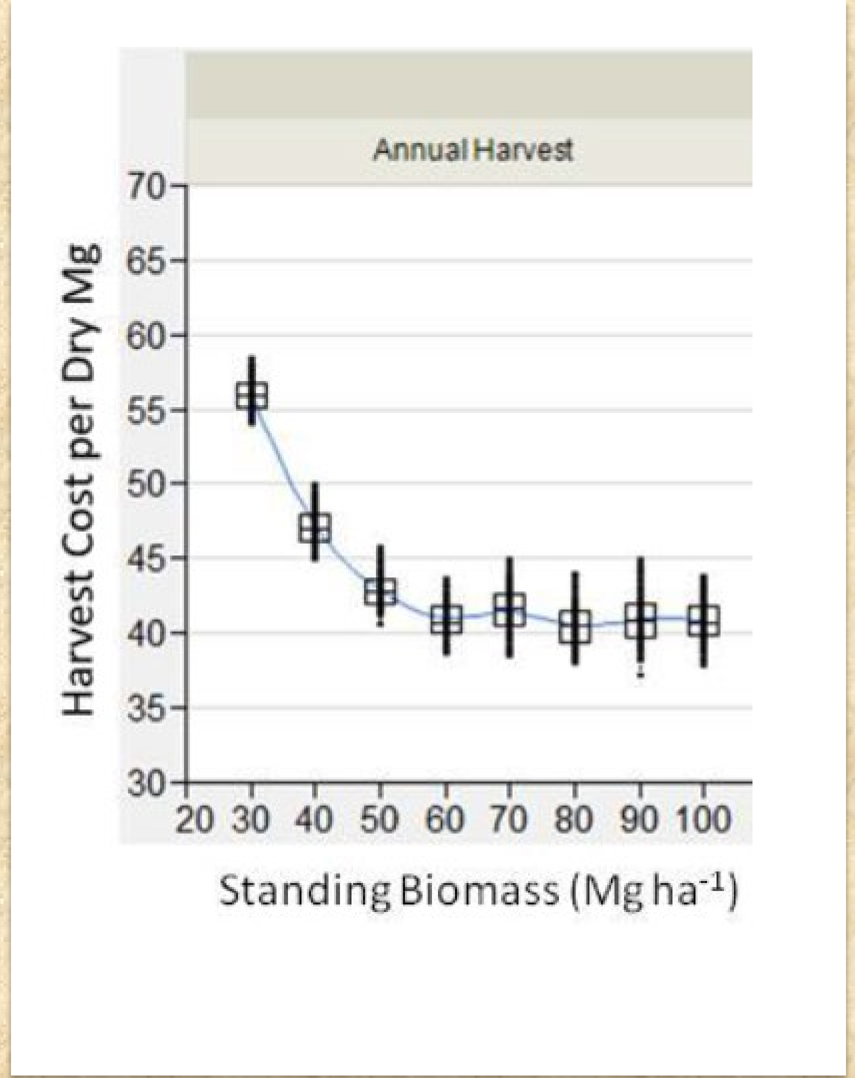
4 - Task 5- Logistic and Economic Modeling (ORNL, WVU, INL)

- **Progress**

– Data and Information incorporated from Tasks 1-4 into different models
– ORNL – IBSAL used to model different harvesting scenarios
– INL- BLM model updated to include pre-processing techniques
– WVU – Optimization model completed for siting facilities

- **Outcomes**

- IBSAL – Simulate harvest scenarios for varying field sizes, collection systems, in varying crop and field conditions, to supply refineries with demands between 110,000 and 880,000 tons/yr
- Target of $54/ dry ton is attainable
- IBSAL – Harvest costs are dependent on standing biomass, location, season of harvest etc.



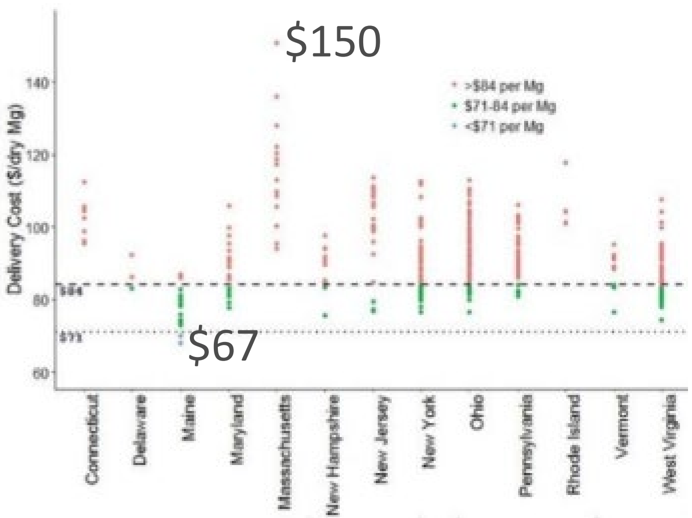
4 - Task 5- Logistic and Economic Modeling (ORNL, WVU, INL)

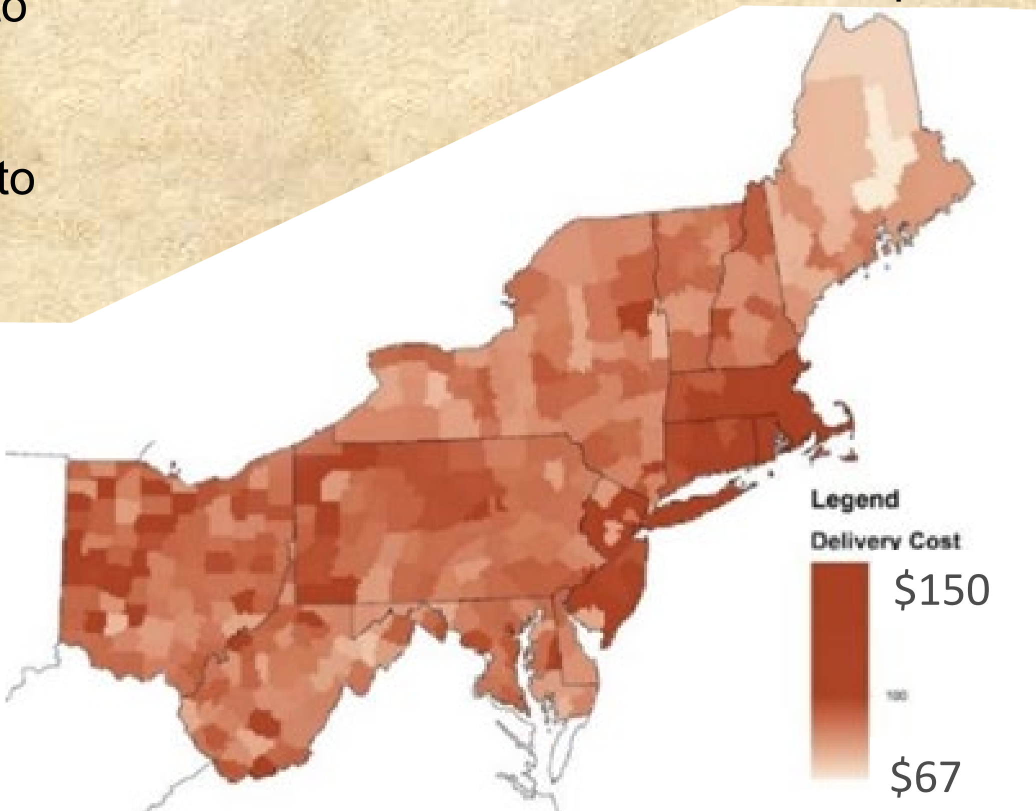
– BLM model - Using high moisture densification and HWE, the blend proportions of willow increased from 21% to 62% and decreased the delivered cost from $83 to $79/dry ton
– Poplar blends were 30-38% at $106 to $116/dry ton
– WVU Model – Spatial distribution of delivered costs ranged between $60 to $135/dry ton ($67 and $150 per Mg)

– Other results summarized in final report

- **Milestones**

– 4 refereed journals-dissertations-thesis
– 9 professional presentations
– Other data summarized in final report





WVU-model Spatial distribution of the regional biomass delivered costs.

Summary and Lessons Learned

- Almost 800 loads (over 1,000 in database) of willow and poplar have been monitored under wide range of crop and site conditions
- Identified range of standing biomass where harvester throughput peaks and fuel use per ton produced is minimized
- Improved understanding of the harvesting, storage and preprocessing over a wider harvesting window to meet biomass supply needs
- Hot Water Extraction (HWE) is a promising pretreatment. Discussions about commercialization underway in several locations
- Drying is the highest cost pre-treatment (over 70 to 90-plus percent in all scenarios).
- Air classification to remove leaf material does not reduce costs, but does improve quality
- Improved understanding resulted in models that better reflect costs for large scale operations
- Costs targets are achievable in the right circumstances
- Working with a diverse set of partners and collaborators creates some challenges, but the value of diversity of perspectives and input is key to success in SRWC systems

Quad Chart Overview (Competitive Project)

Timeline

- Project start date: Nov. 13, 2015
- Project end date: Sept. 30, 2020

	FY20 Costed	Total Award
DOE Funding	$316,855	$2,317,381
Project Cost Share	$313,725	$1,512,815 ESF - $501.075 NYSERDA – $208,048 Honeywell $637,630 WVU $98,909 ABS $37,240 GWR $29,912

Project Partners*

- Partners: SUNY ESF, Applied Biorefinery Sciences, GreenWood Resources, Idaho National Lab, Oak Ridge National Lab, University of West Virginia
- Collaborators: Celtic Energy Farms, Honeywell International, NYSERDA, ReEnergy, USDA NRCS

Project Goal

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

End of Project Milestone

- BETO milestone (20FS24) to develop feedstock supply systems
    - Target: $84/dry ton cost to throat of conversion reactor (harvesting costs < $54/dry ton)
- BETO Barriers Addressed: Sustainable Harvesting (Ft-D), Availability of Quality Feedstock (Qt-A), Feedstock Availability and Cost (Ft-A)

Funding Mechanism

Advanced Biomass Feedstock Logistics Systems II (DE-FOA-0000836) , 2013

Questions

Additional Data – IBSAL Model Results for Leaf On/Off

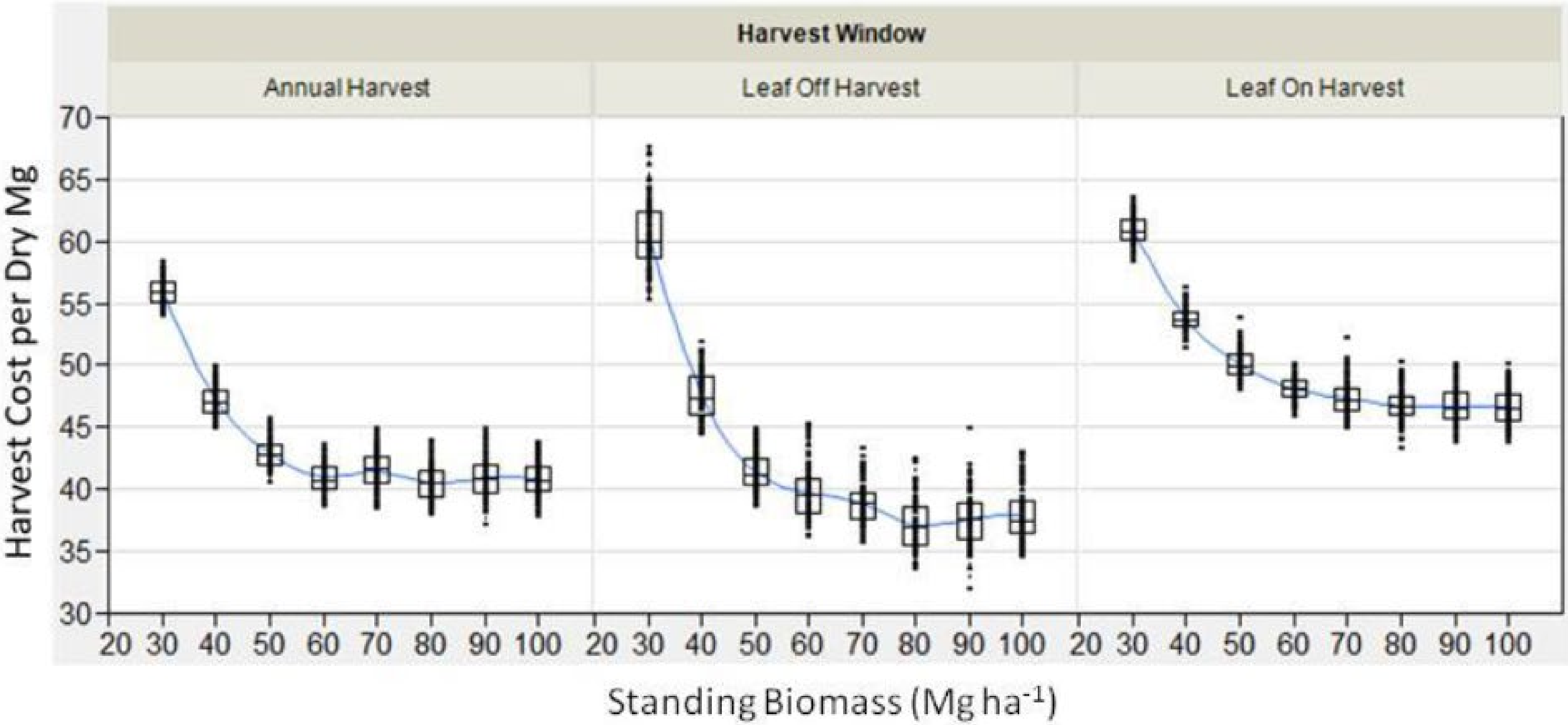
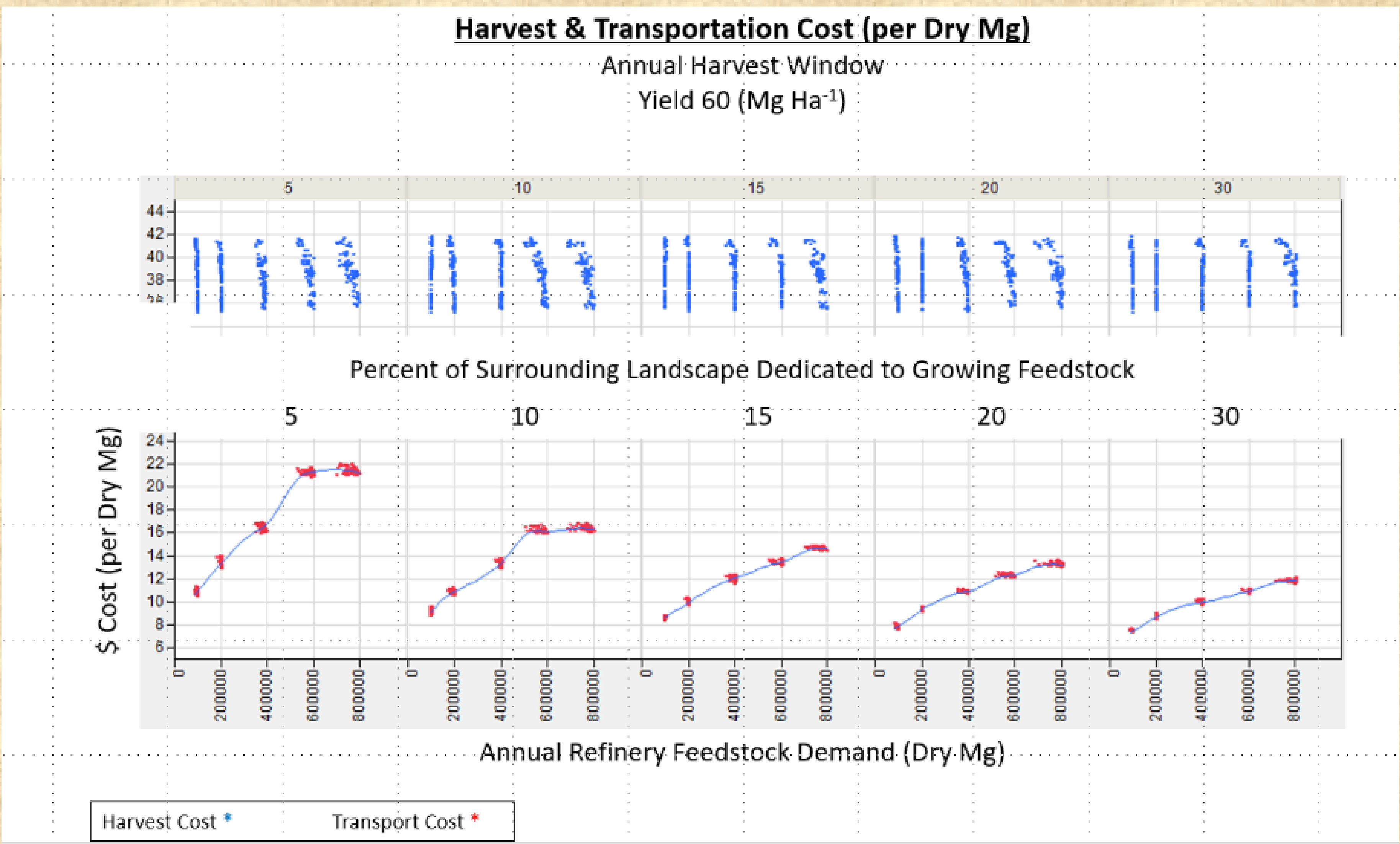


Figure 5.2.2: Harvest cost per dry Mg as a function of standing biomass and harvest window.

Additional Data – IBSAL Results for Transportation Costs



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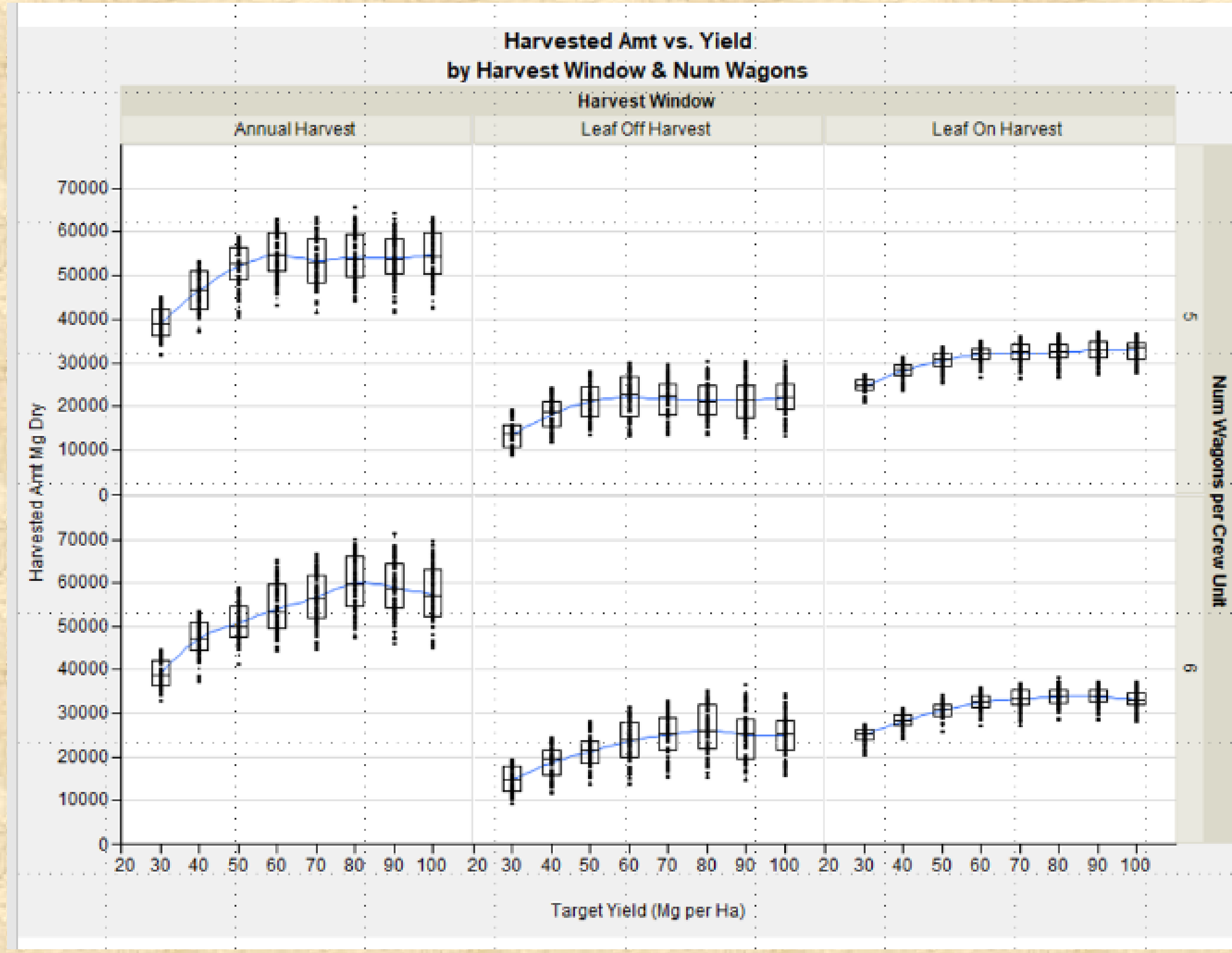
Additional Data – IBSAL Results for Harvesting Amounts



This chart shows the total harvested amount for the single crew during the harvest window.

Note that the Annual harvest window, the amount should roughly total up the Leaf On and Leaf Off harvest windows.

Even though the Leaf Off harvest window can harvest more per workday than Leaf On (see previous chart on Harvest Amt per Workday), the Leaf On harvest window has significantly more workdays than Leaf Off.

3 – Task 3- Preprocessing and Blending (INL)

Objective: Use air classification processing to improve feedstock quality by removal of low quality material (leaves)

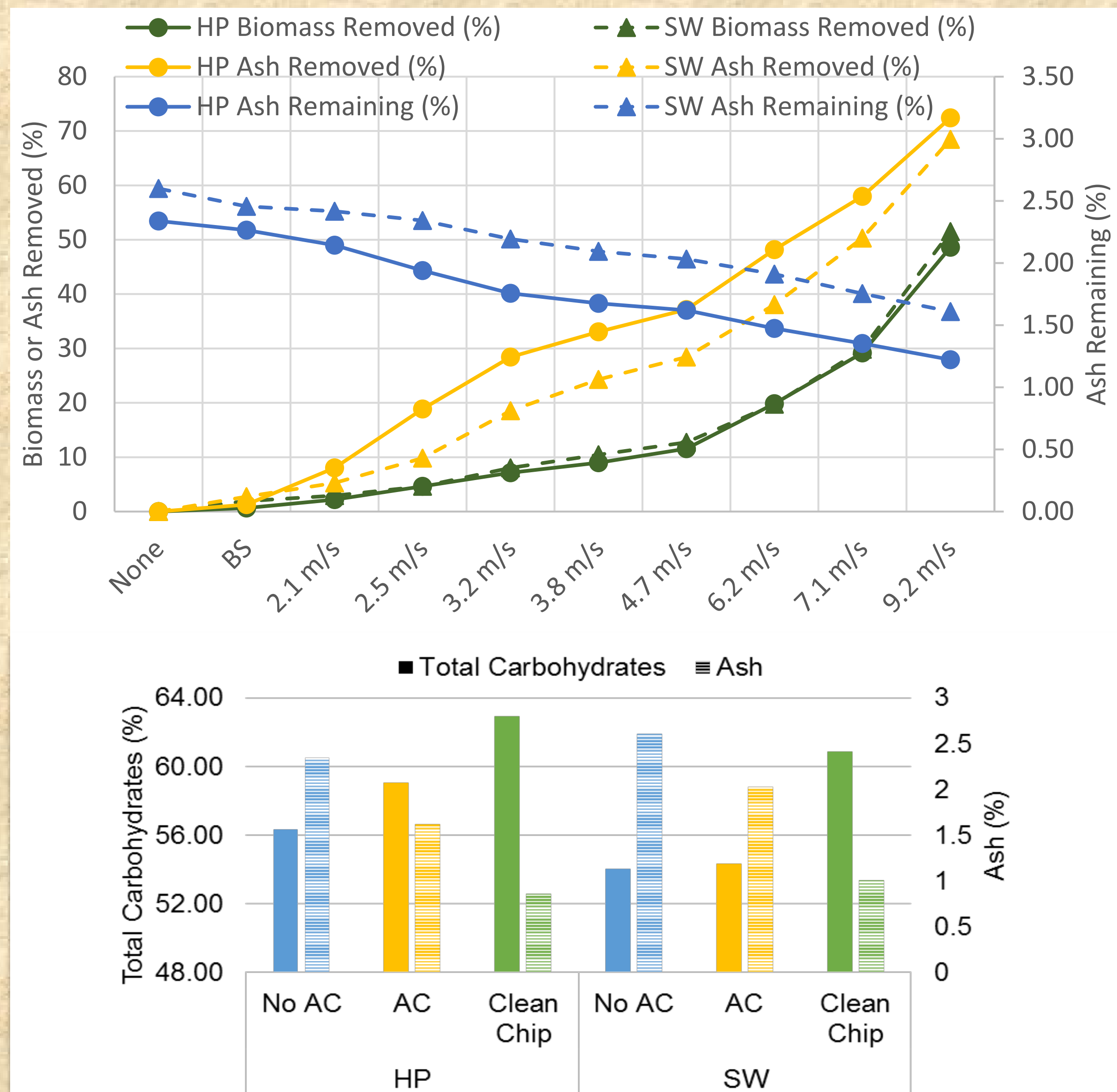
Top Figure:

- Air classification removed leaves and reduced ash

Bottom Figure:

- Leaf removal increased hybrid poplar sugar content from 56% to 61%.

Air classification can reduce processing costs by removing leaves prior to drying.



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Publications

Publications

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