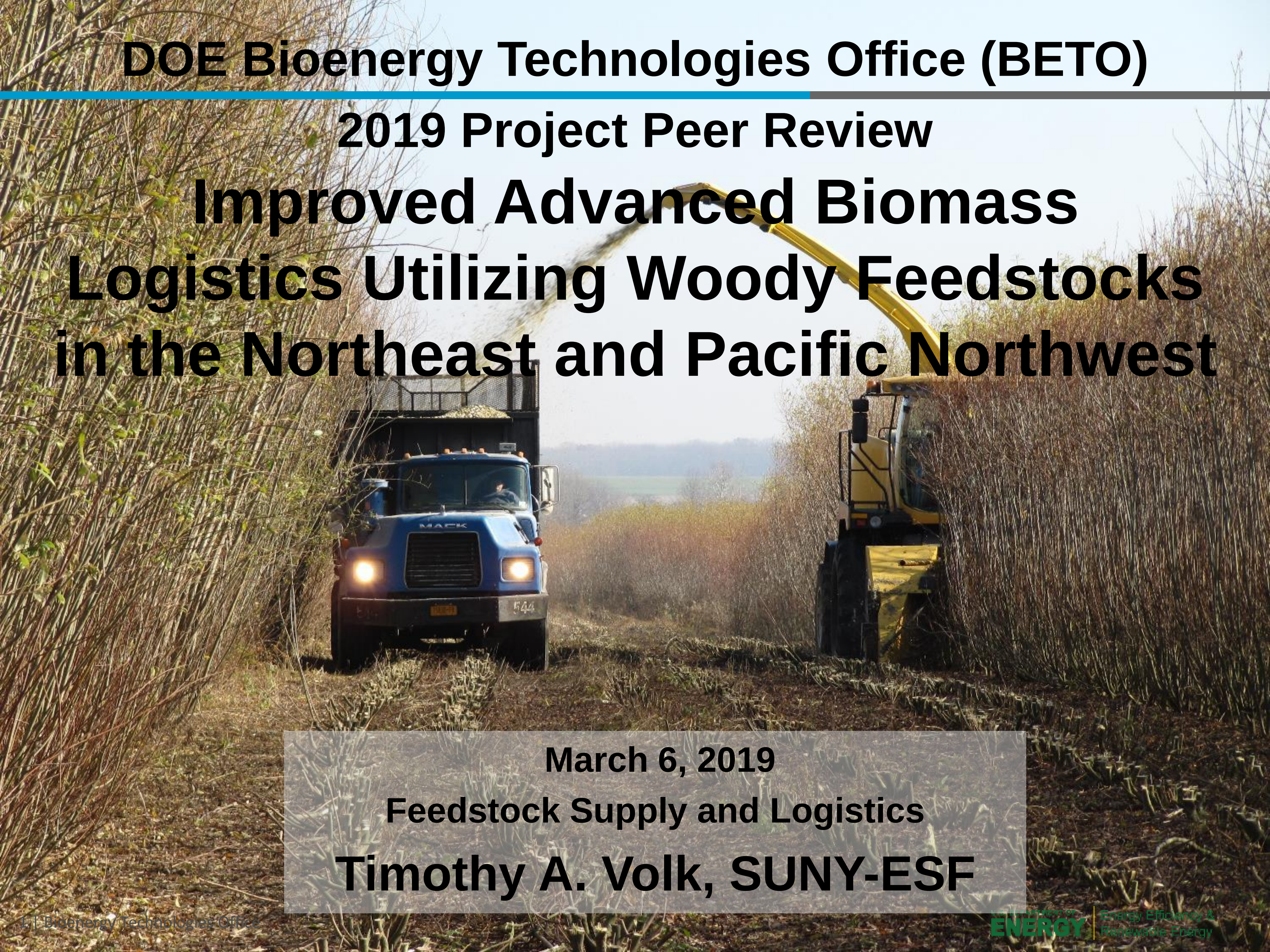


# DOE Bioenergy Technologies Office (BETO)

## 2019 Project Peer Review

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

March 6, 2019

Feedstock Supply and Logistics

**Timothy A. Volk, SUNY-ESF**

# 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
  - Target is **$84 dry ton** total cost to throat of conversion reactor
- SRWC cost is a barrier; harvesting and logistics are main components
- Lack of experience and skepticism among growers and end users about harvesting and quality of the material are barriers to expansion
- Very little work done on how storage and preprocessing of SRWC impacts quality and costs

# Quad Chart Overview

**Timeline**
- Project start date: Nov. 13, 2015
- Project end date: June 30, 2019
- Percent complete: 85%

**Barriers addressed**

Ot-A: Availability of Quality Feedstock

Ft-D: Sustainable Harvesting

| | Total Costs Pre FY17** | FY 17 Costs | FY 18 Costs | Total Planned Funding (FY 19-Project End Date) |
|---|---|---|---|---|
| **DOE Funded** | ESF: $402,065<br><br>**Total: $402,065** | ESF: $498,657<br>WVU: $1,702<br>GWR: $14,455<br>ABS: $0<br><br>**Total: $514,813** | ESF: $443,866<br>WVU: $34,218<br>GWR: $16,345<br>ABS: $3,508,<br><br>**Total: $497,937** | **$2.3 million** |
| **Project Cost Share*** | ESF:$158,667<br>Honeywell: $433,294<br>NYSERDA: $216,048,<br><br>**Total: $808,009** | ESF: $112,846<br>Honeywell: $0<br>NYSERDA: $58,819<br>WVU: $4,165<br>GWR: $12,392<br><br>**Total: $188,222** | ESF: $94,225<br>NYSERDA: $6,462<br>WVU: $19,114<br>GWR: $9,067<br>ABS: $12,832<br><br>**Total: $141,700** | **$1.4 million** |

- **Partners: SUNY ESF (), ABS (), GWR (), UWV (), INL (), ORNL (), Honeywell ()**

**Objective**

Target is $84 dry ton total cost to throat of conversion reactor

**End of 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

# Terms and Acronyms

EMC – (effective material capacity) – Amount of biomass processed per hour by a machine or the system (Mg/hr)

EFC – (effective field capacity) – Area of cropland processed per hour by the harvester (Ha/hr)

CSFC – (crop specific fuel consumption) – Amount of fuel consumed per Mg of biomass produced (L/Mg)

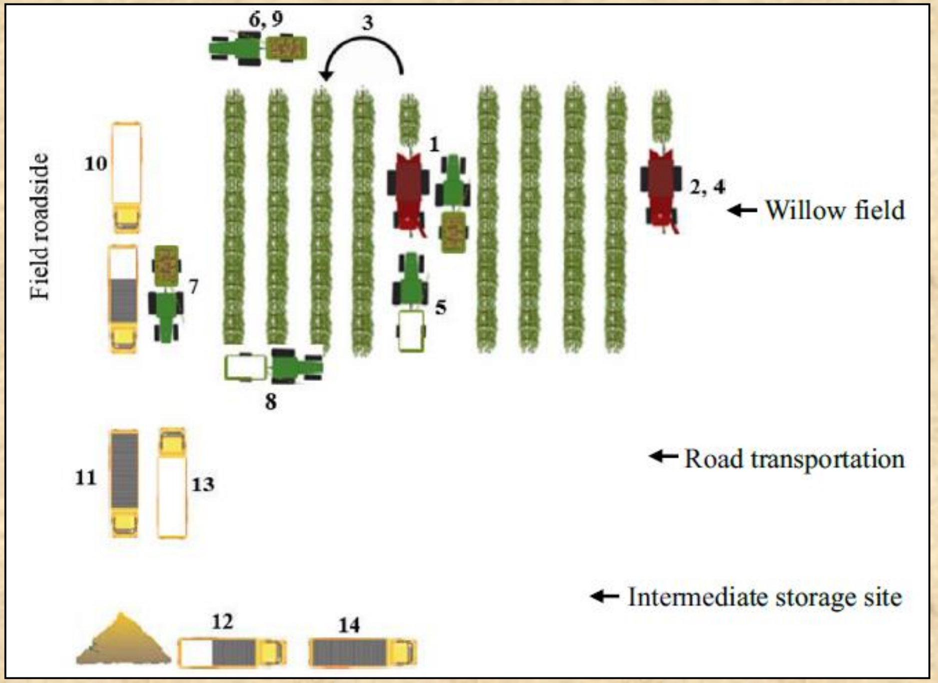
HWE – (hot water extraction) – Preprocessing technology where biomass is cooked in hot water for a period of time resulting in extract with sugars and other compounds and woody residue with improved quality characteristics

NIR – (near infrared) – Spectroscopy is correlated with compositional data generated from traditional wet chemical techniques, to develop rapid calibration models

SRWC – (short rotation woody crops) – Woody plants (trees or shrubs) grown on short rotation of 10 years or less primarily as a bioenergy feedstock. The SRWC focused on in this project hybrid poplar and shrub willow

# 1 - Project Overview

- Harvesting and transportation makes up 40 – 60% of the delivered cost of SRWC (Frank et al. 2018) and are the 2nd and 3rd largest source of GHG emissions (Yang et al. in review)
- System throughput decreases up to 65% from harvester throat to delivery to short term storage (Eisenbies et al. 2014)
- Changes in SRWC biomass quality and impacts of pretreatment techniques along the supply chain are not well understood
- Large scale SRWC fields provides unique opportunity to collect harvesting and logistics data that can be used in models to optimize system for expansion



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# 2 – Approach (Management)

- **Team**
  - Includes universities (2), national labs (2), commercial partners ranging in size from small to large and state agency

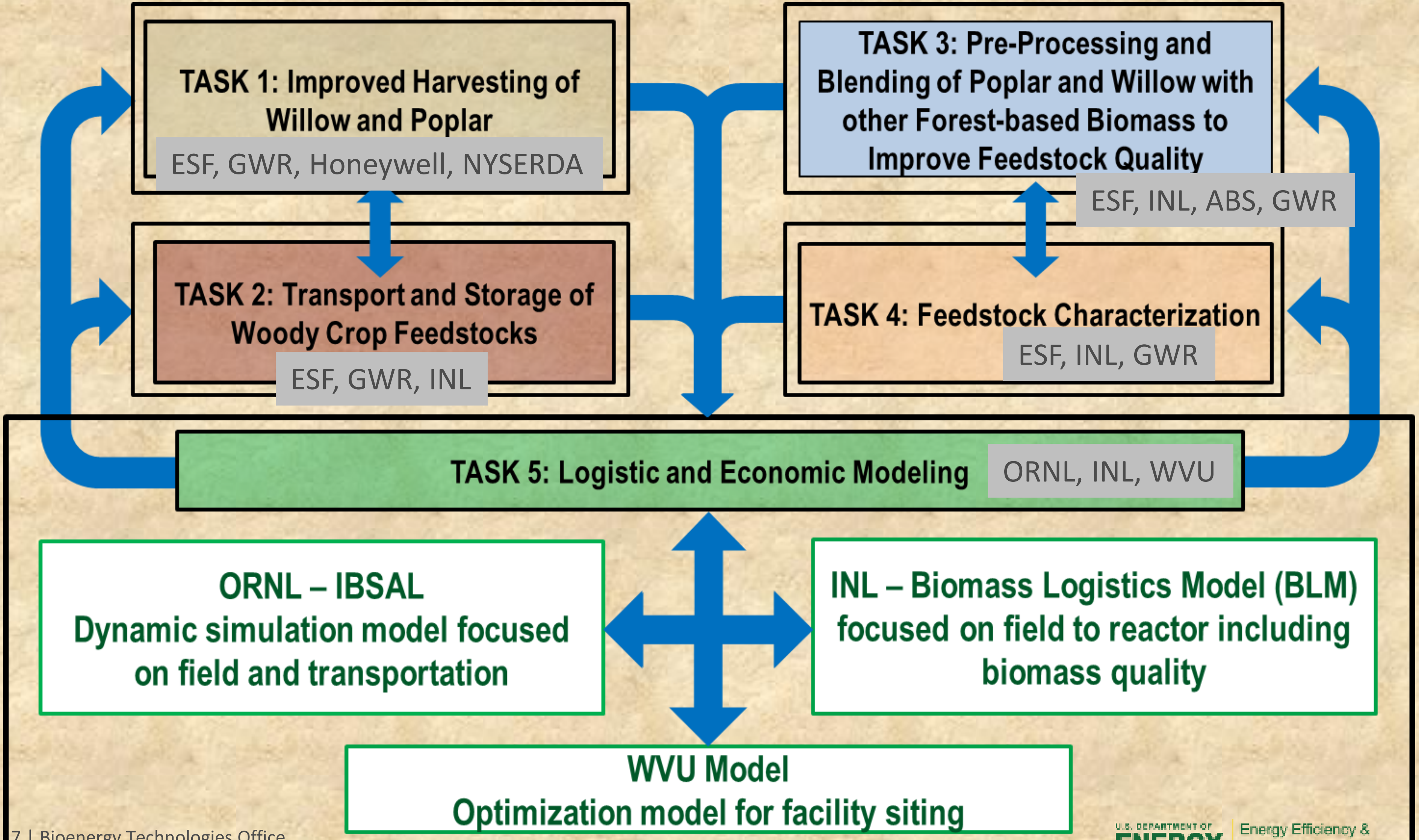
- **Management Approach**
  Iterative interaction between in data collection and modeling: Harvesting trials and data collection ➔ Model Simulation/Optimization ➔ Harvesting trials and data

  - Two monthly conference calls: 1. entire team and 2. modeling partners
  - Quarterly assessment of milestones using PMP
  - Task-specific conference calls
  - Annual meetings organized around harvests
  - Go/No-Go meeting midway completed March 2017

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

# 2 – Approach (Technical) - Five Integrated Tasks

## Project Integration



# 2 – Approach (Technical)

- **Critical Success Factors**
  - Achieve the $84 per dry ton feedstock cost at the throat of the reactor
  - Improve system efficiency and expand harvesting window
  - Develop system to affordably monitor quality (e.g. moisture content, ash content, sugars, lignin) along supply chain
  - Incorporate preprocessing technologies to maintain/improve biomass feedstock quality
  - Optimize SRWC harvesting and logistics through modeling

- **Challenges**
  - Variety of field conditions and objectives among commercial partners growing willow creates opportunities and challenges
    - Coordinating timing and location of harvesting trials
    - Tracking feedstock quality through supply chain
  - Changing weather patterns
  - Uncertain end use markets in the future
  - Adapting NIR techniques for fresh biomass samples

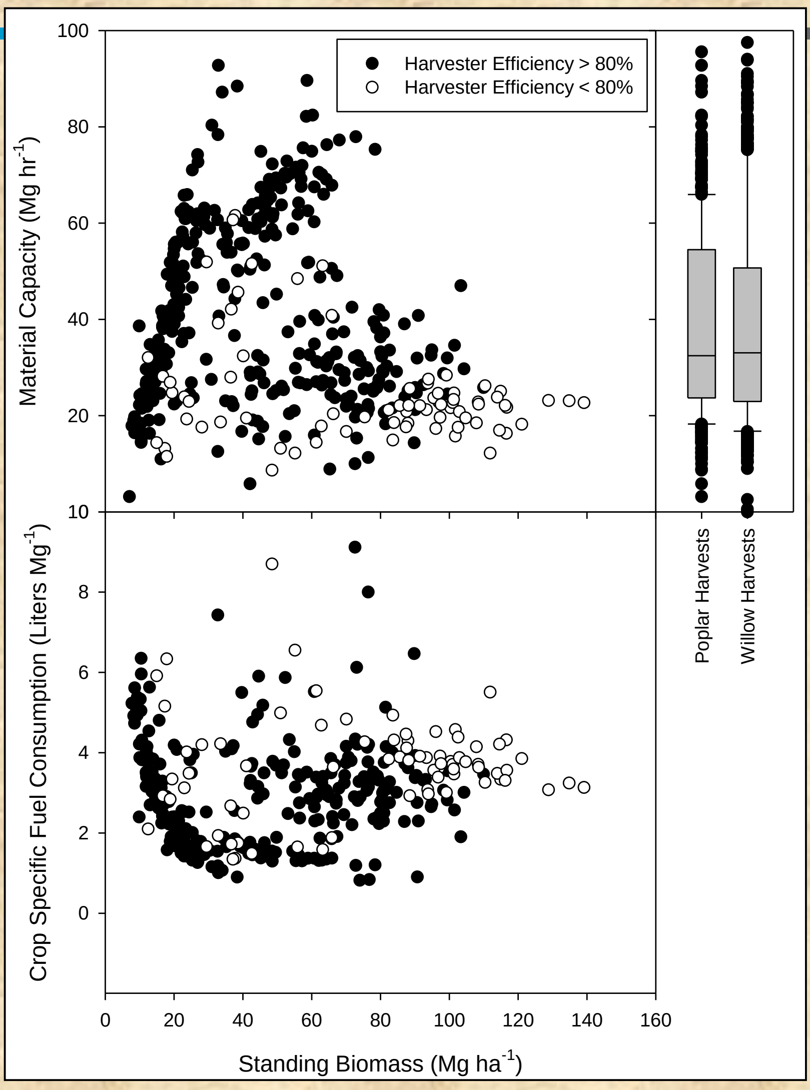
# 3 - Technical Accomplishments/ Progress/Results

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

- **Progress**
  – Developed data collection systems and linked them with New Holland software (Intelliview/PLM) that monitors harvester parameters (i.e. fuel use, engine capacity etc.)
  – Collected and processed hundreds of biomass samples

- **Tech Accomplishments**
  – Created and shared largest data set of SRWC harvesting with 1,075 (636 willow, 439 poplar) monitored loads (775 from this project)

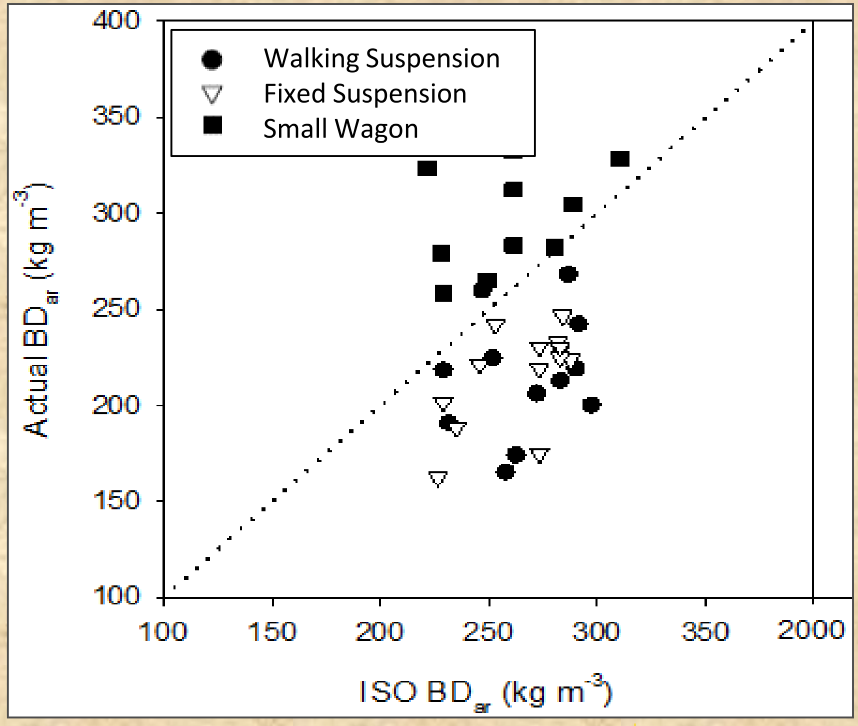
- **Milestones/Status**
  – Three manuscripts print.  Four manuscripts in preparation.




Material capacity (Mg/hr) and crop specific fuel consumption (Liters/Mg) for 439 poplar loads

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

- **Progress**
  - Completed 3 chip storage pile studies and a bulk density study
- **Tech Accomplishments**
  - Willow actual bulk density is variable and is not well represented by ISO standard bucket method
- **Milestones/Status**
  - Two papers in review, two in preparation
  - Addressed specific data requests to improve models (Task 5)

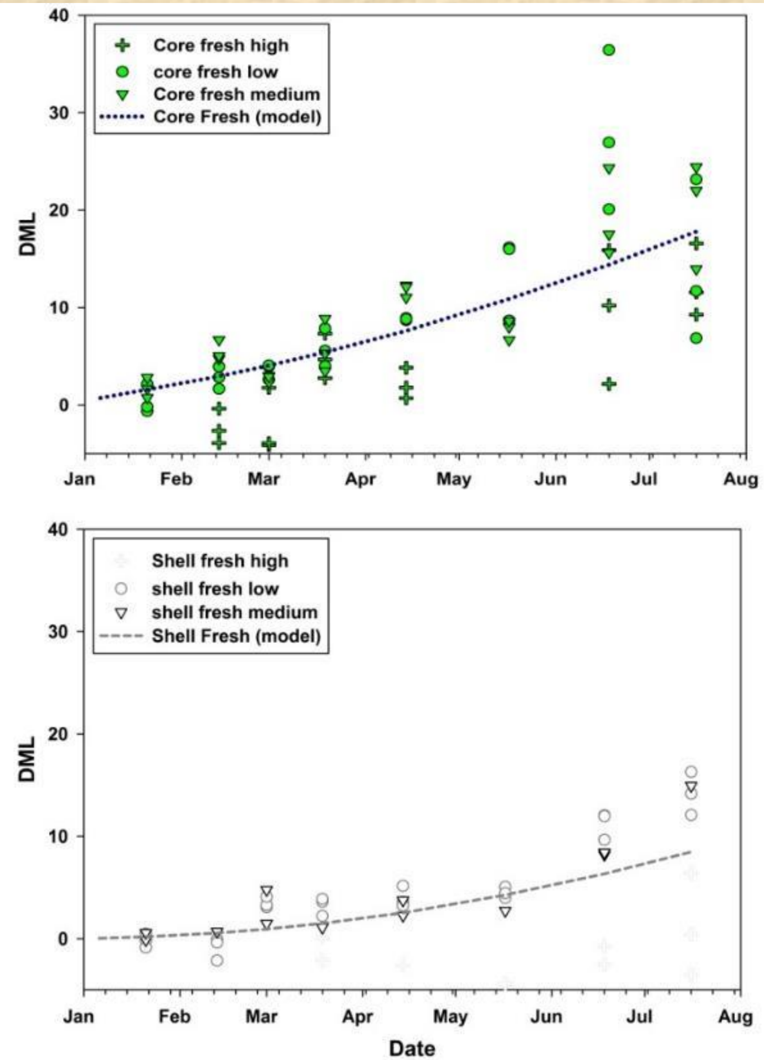



Top: Collecting actual bulk density data.
Bottom: No relationship between actual and ISO method bulk density measurements.

# 3 – Task 2- Storage and Transport (ESF, GWR, INL)

## Tech Accomplishments

- Cover, time of harvest and pile location impact dry matter loss and other changes in chip quality (moisture, HHV, LHV, ash, composition)
- Raises issues with how growers are paid for biomass




Willow dry matter loss in pile core (top) and shell (bottom) over 6 months of storage.



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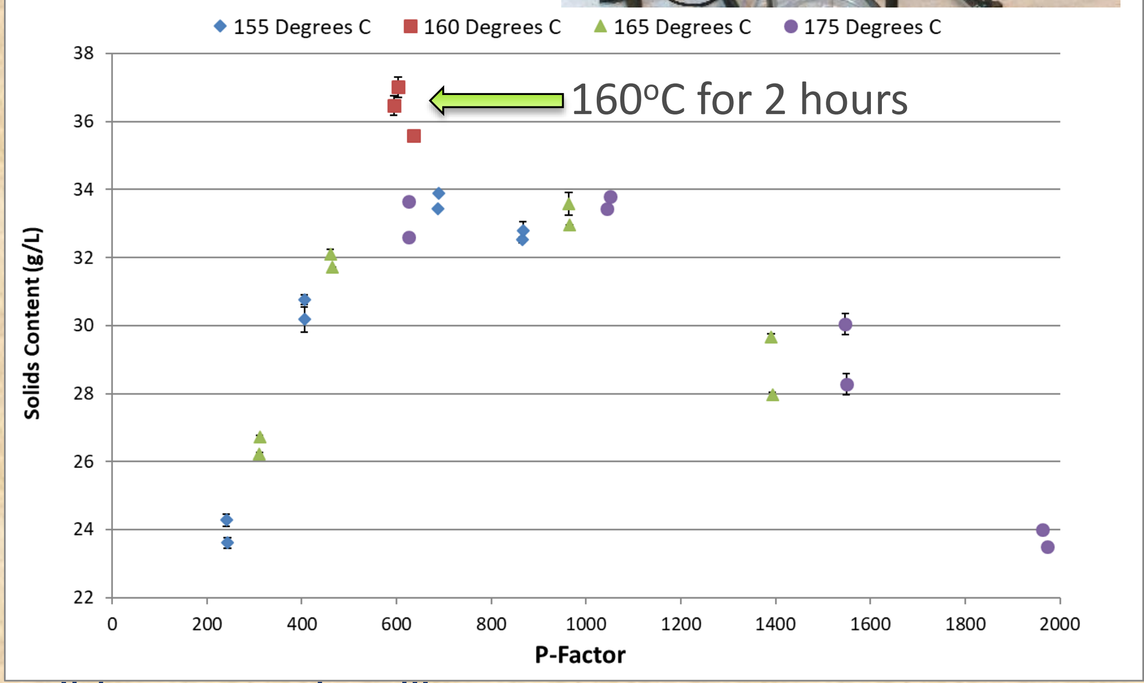
# 3 – Task 3- Preprocessing and Blending (Hot Water Extraction – ESF, ABS)

- **Progress**
  - Completed time-temperature curves for willow hot water extraction (HWE) runs
  - PDU runs of leaf on and leaf off of willow and poplar at INL

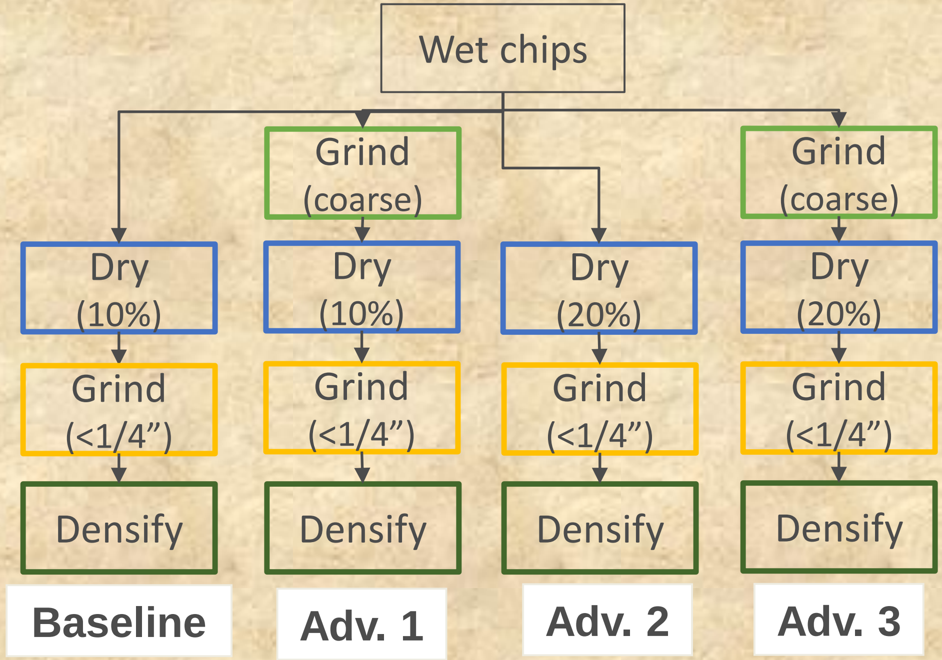
- **Tech Accomplishments**
  - Mass removal for HWE optimized at 160C for 2 hours
- **Milestones/Status**
  - Four papers on PDU and HWE extraction published, one currently in preparation

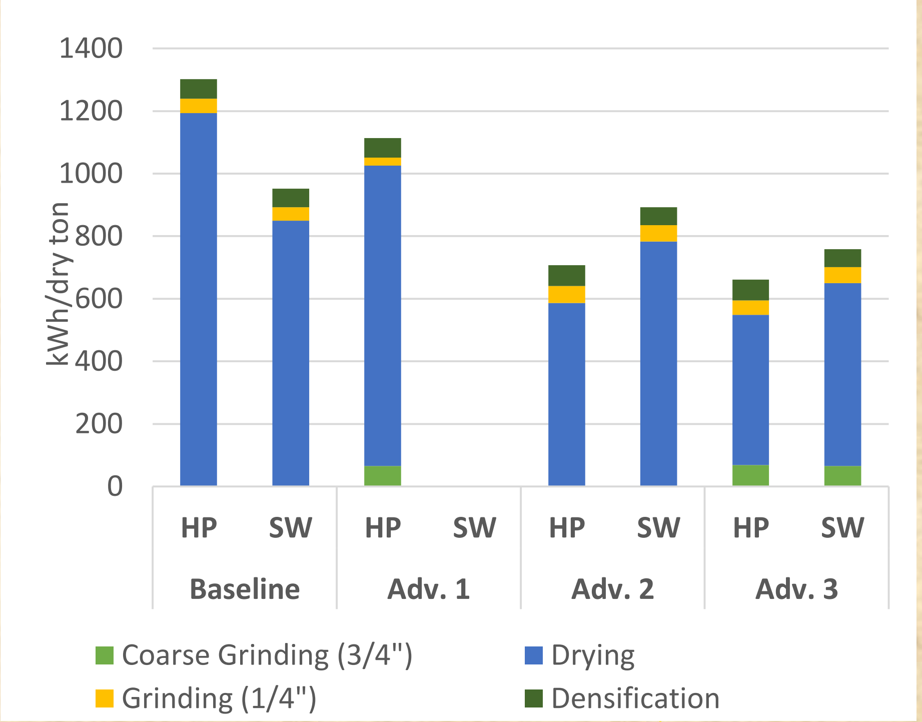




Solids content in willow HWE extract across a range of processing time and temperatures (P-factor)

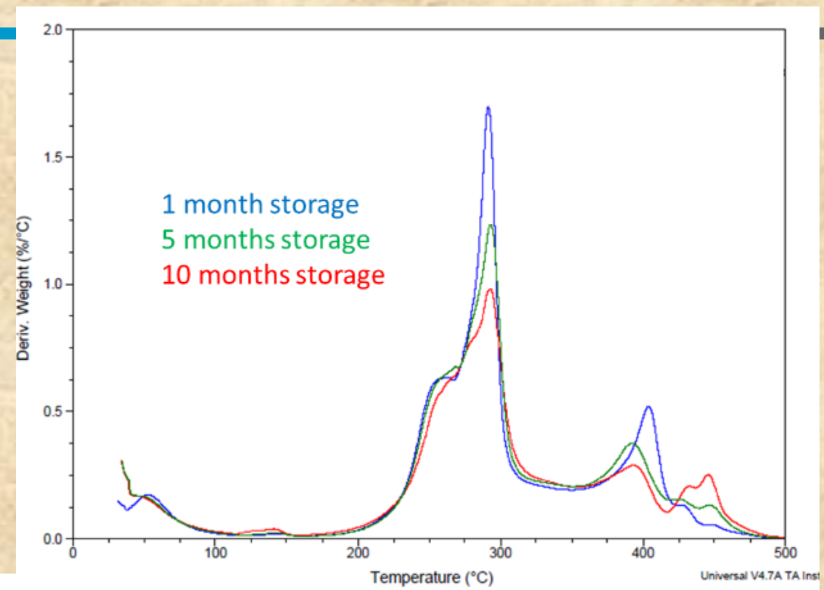
# 3 – Task 3- Preprocessing and Blending (PDU – INL, ESF, GWR, ABS)

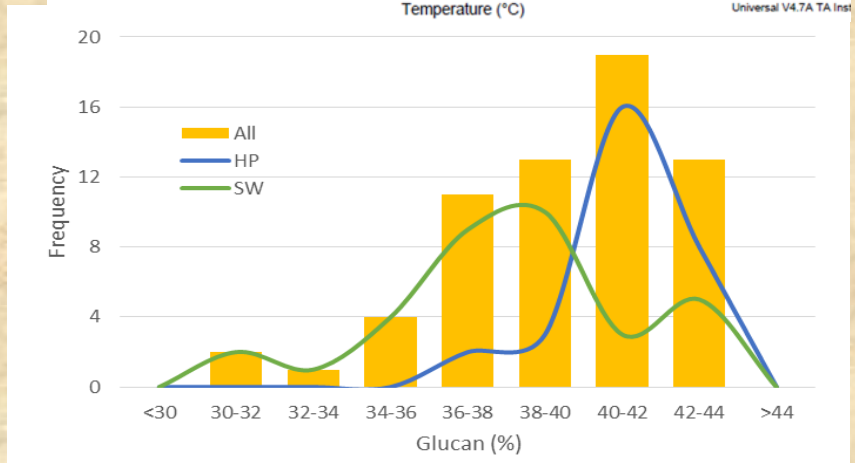
- **Tech Accomplishments**
  - Of four techniques tested at INL, the combination of **high moisture densification** and **coarse grinding** resulted in lowest energy consumptions (Adv. 2 & 3)
  - Initial moisture content has large impact on energy consumption



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



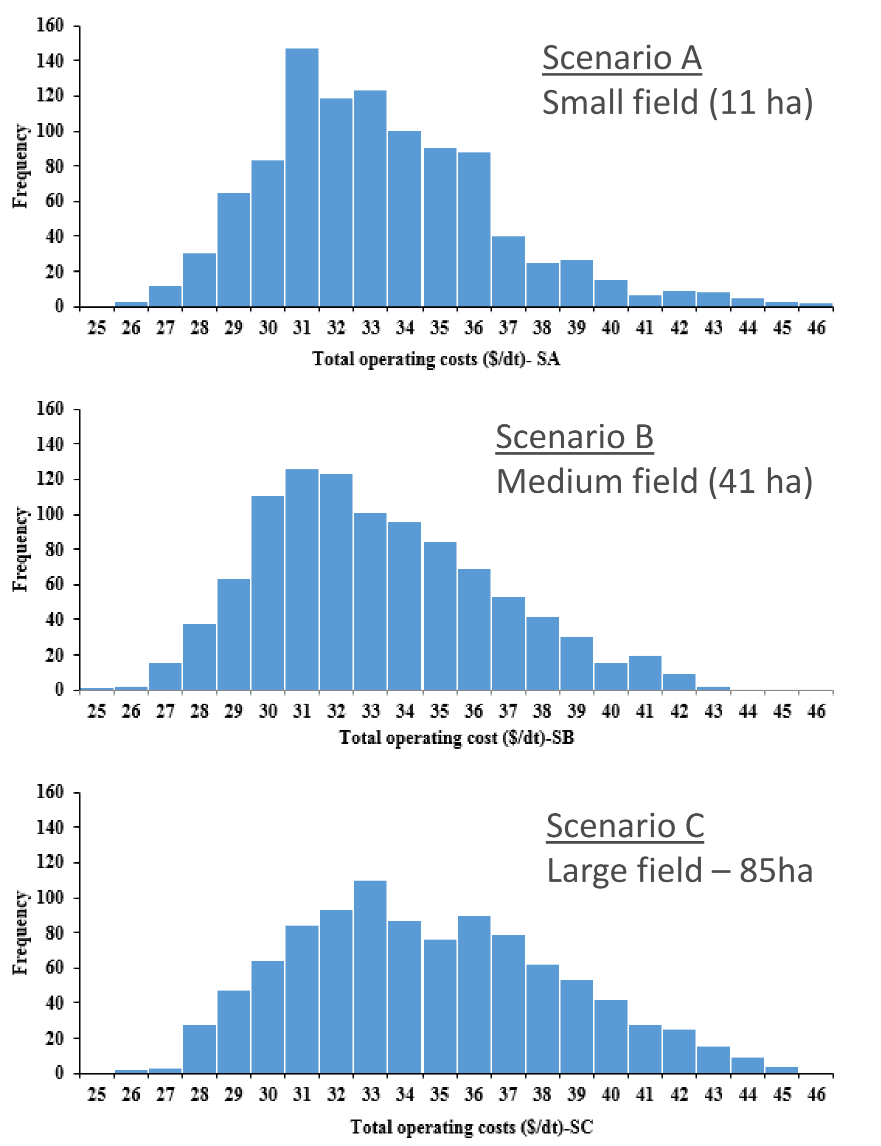




Top: TGA of willow chips during storage. Bottom: Frequency of glucan levels for fresh willow and poplar

- **Progress**
  - Wet chemistry completed at INL for 77 willow and poplar samples
  - Characterized willow samples from storage trials using TGA
- **Tech Accomplishments since 2015**
  - Updated NIR models still have low $R^2$ (0.33 – 66) and low RMSECV (0.59 – 2.08)
  - TGA analysis suggests lignin and carbohydrates decay at similar rates in storage piles
- **Milestones/Status**
  - Protocols for developing NIR models have been developed and updated models completed
  - Almost 1,500 samples added to bioenergy library

# 3 – Task 5- Logistic and Economic Modeling (ORNL, WVU, INL)

- **Progress**
  - ORNL – IBSAL used to model different harvesting scenarios
  - INL- BLM model updated to include HWE pre-processing, which has ROI of 19 – 130% based on scale and other factors
  - WVU – Optimization model completed for siting facilities
- **Tech Accomplishments**
  - IBSAL – harvesting costs range from $26-45/Mg
  - Lowest cost occurs when silage trucks are collection vehicles
  - Crop yield and collection equipment have highest impact on costs

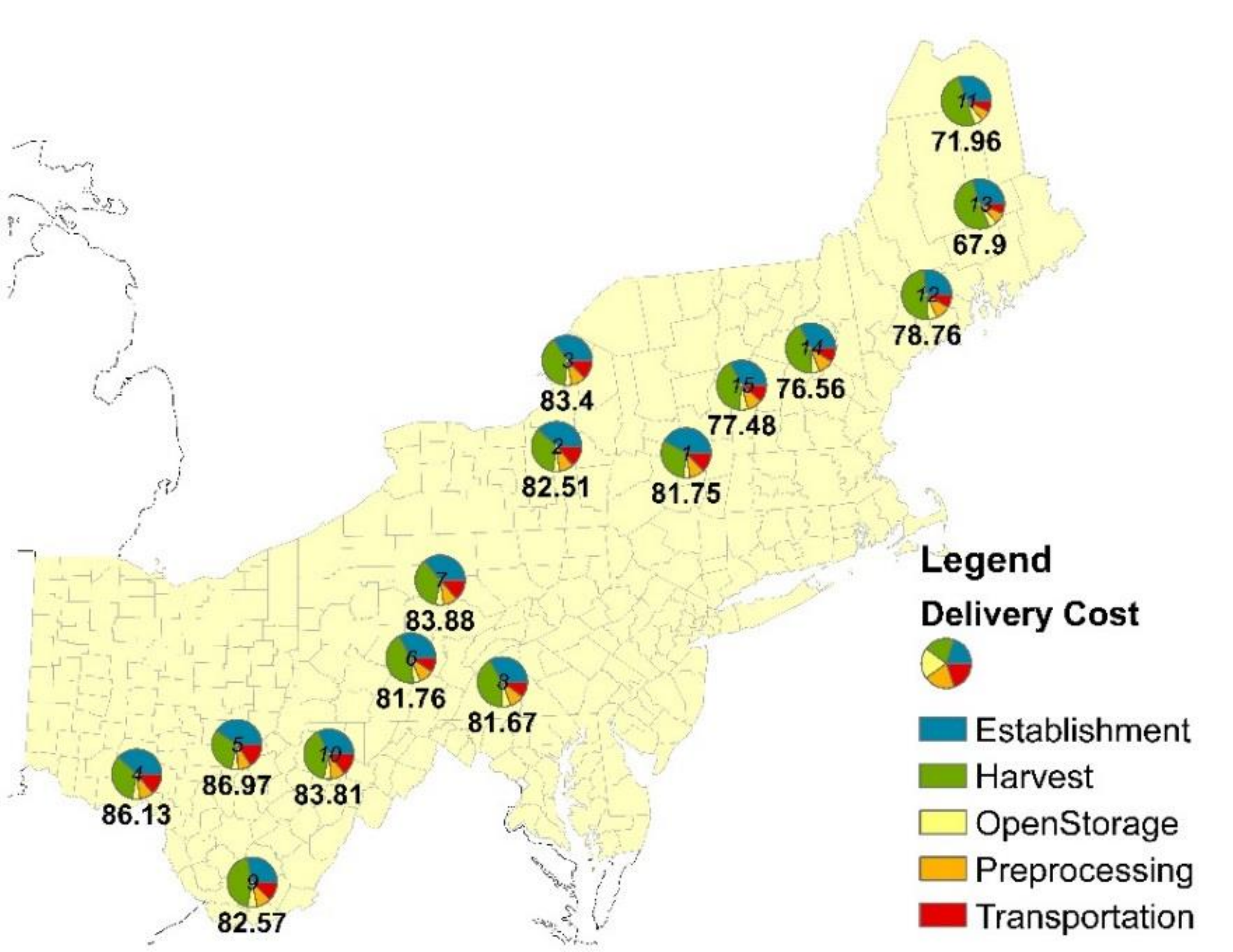



Distribution of harvesting costs ($/Mg) for field size different scenarios (Ebadian et al. 2018)

# 3 – Task 5- Logistic and Economic Modeling (ORNL, WVU, INL)

- **Tech Accomplishments**
- WVU model used 11 suitability indices, including harvesting scenarios and social factors, to identify 15 potential locations for biorefineries
- Biomass costs to supply optimal locations range from $72 – 87/Mg

- **Milestones/Status**
– Two papers completed, three in preparation




Biomass costs for optimal biorefinery locations in the NE base on UWV model.

# 4– Relevance

- **Reducing harvesting and logistics costs while maintaining biomass quality along the supply chain**
- **Directly addresses BETO and FSL identified barriers and challenges**
  - "To meet quality requirements of conversion facilities, feedstock supply and logistics R&D will need to improve feedstock quality from harvest and collection through delivery while also meeting conversion performance and cost goals" (Ot-A)
  - "Logistics costs need to be reduced while improving biomass quality and processing efficiency" (Ft-D)
- **Addresses FSL target to deliver biomass to the throat of the reactor for less than $84/ton**
  - Combination of large scale harvests and modeling to optimize harvesting and logistics with growers and end users (over 850 tons of biomass used for biopower and CHP, which has greatly increased end user comfort with this feedstock)
  - Quality of material tracked along the supply chain and through storage for different times of the year
  - Preprocessing techniques, including HWE, identified to maintain or improve biomass quality with minimal cost

# 5 - Future Work

- **Task 1 Improved Harvesting of Woody Crops**
  - Publish results from large data set, make it publically available, and develop best practices for SRWC harvesting
- **Task 2 Transport and Storage**
  - Publish results from storage trials and create best practices for year round supply of SRWC using results from storage trials
- **Task 3 Pre-Processing and Blending**
  - Complete PDU run with HWE material and build into BLM model
  - Develop best practices for preprocessing to minimize costs and ensure quality targets are met
  - Complete HWE runs with mixed SRWC and hardwoods
- **Task 4 Feedstock Characterization**
  - Complete NIR model for SRWC and steps needed for improving models
  - Make data available in INL Bioenergy Library
- **Task 5 Logistic and Economic Modeling**
  - Complete analysis of storage locations impact on costs
  - Complete a supply chain design incorporating advanced preprocessing for both willow and poplar that meets costs <$84/dry ton at the throat of the reactor, quality requirements, and 1,000 Mg/day supply

# Summary

- 775 loads (over 1,075 in database) of willow and poplar have been monitored under various crop and site conditions
- Data being used for modeling of expansion and best practices
- Storage trials provide data on changes in quality over time, but analysis suggest composition is not changing as expected
- Data set of 77 samples developed and used to build NIR models for rapid assessment of quality
- PDU runs on leaf on and leaf off poplar and willow provide insights on best pathways for preprocessing
- Hot water extraction data incorporated into BLM model
- Key factors influencing costs for harvesting being identified and solutions modeled
- Delivered biomass cost for 15 potential biorefineries ranged from $68 to $87/dry Mg based on site and social factors.

# Questions

# Extra Slides

# Publications, Patents, Presentations, Awards, and Commercialization

Refereed Publications

Task 1 Vanbeveren, SPP, R Spinelli, M Eisenbies, J Schweier, B Mola-Yudego, N Maganotti, M Acuna, I Dimintriou, and R Ceulemans. 2017. Mechanized harvesting of short-rotation coppices. Renewable & Sustainable Energy Reviews. 76:90-104

Eisenbies, MH, TA Volk, J Espinoza, C Gantz, A Himes, J Posselius, R Shuren, B Stanton, B Summers. 2017. Biomass, spacing and planting design influence cut-and-chip harvesting in hybrid poplar. Biomass and Bioenergy. 106:187-190

Volk, TA, JP Heavey, MH Eisenbies. 2016. Advances in shrub-willow crops for bioenergy, renewable products, and environmental benefits

Task 2 Eisenbies, M., O. Therasme, T.A. Volk., K. Hallen. In review. Short rotation willow chip bulk density and a comparison of bulk density determination methods. Biomass and Bioenergy.

Therasme, O., M. Eisenbies, T.A. Volk. In review. Overhead protection affects fuel quality and natural drying of leaf on wood biomass storage piles. Forests.

Task 3 Williams, C. L.; Emerson, R. M.; Hernandez, S.; Klinger, J. L.; Fillerup, E. P.; Thomas, B. J., 2018. Preprocessing and Hybrid Biochemical/Thermochemical Conversion of Short Rotation Woody Coppice for Biofuels. Front Energy Res, 6 (74).

Emerson, R. M.; Hernandez, S.; Williams, C. L.; Lacey, J. A.; Hartley, D. S., 2018. Improving bioenergy feedstock quality of high moisture short rotation woody crops using air classification. Biomass and Bioenergy, 117, 56-62.

Therasme, O., T.A. Volk, A.M. Cabrera, M.H. Eisenbies, T. Amidon. 2018. Hot Water Extraction Improves the Characteristics of Willow and Sugar Maple Biomass With Different Amount of Bark. Frontiers in Energy Research. doi: 10.3389/fenrg.2018.00093

Eisenbies MH, TA Volk, S Shi, TE Amidon. 2019. Influence of blending and hot water extraction on the quality of wood pellets. Fuel 241:1058-1067.

Task 5 Frank, J., Brown, T. Volk, T.A. Heavey, P., Malmsheimer, R. 2018. A stochastic techno-economic analysis of shrub willow production using EcoWillow 3.0S. Biofpr. DOI: 10.1002/bbb.1897

Ebadian, M., M.E. Shedden, E Webb, et al. 2018. Impact of Parcel Size, Field Shape, Crop Yield, Storage Location, and Collection Equipment on the Performance of Single-Pass Cut-and-Chip Harvest System in Commercial Shrub Willow Fields. BioEnergy Research 11 (2), 364-381

# Publications, Patents, Presentations, Awards, and Commercialization

Manuscripts Currently in Preparation or Review for Refereed Journals

Task 1 Eisenbies, MH, TA Volk, D Pegoretti, J Espinoza, C Gantz, A Himes,R Shuren, B Stanton, B Summers. K Hallen. In preparation. Paper on crop specific fuel consumption in Poplar

Eisenbies, MH, TA Volk, D Pegoretti, K Hallen. In preparation. Paper on crop specific fuel consumption in Willow

D Pegoretti, TA Volk, Eisenbies, MH, In preparation. Paper on crop attribute effects on harvester performance

D Pegoretti, TA Volk, Eisenbies, MH, In preparation. Paper on harvesting effects on nutrient dynamics

Task 2 Therasme, O., M. Eisenbies, T.A. Volk. In Review. Overhead protection affects fuel quality and natural drying of leaf-on woody biomass storage piles. Forests

Eisenbies MH, TA Volk, O Therasme, K Hallen. In Review. Shrub willow bulk density change based on measurement methods, collection vehicles, and crop attributes. Biomass and Bioenergy

Therasme, O., T.A. Volk. M. Eisenbies. In Preparation. Dynamics of dry mater loss and fuel quality changes of a leaf-off short rotation woody biomass storage pile.

Task 3 Therasme, O., TA Volk. In preparation. Life cycle assessment of short rotation woody biomass conversion into biofuel and electricity.

Task 4

Task 5 Shedden, M., M. Ebadian, E. Webb, J. Coble, T. Volk, D. Pegoretti Leite de Souza, M. Eisenbies, J. Ostrowski, and K. Hallen. In preparation. Evaluate the operational reliability of single-pass cut-and-chip harvest system in commercial shrub willow fields.

Wang, Yuxi, J. Wang, D. Hartley, J. Schuler, T. Volk, and M. Eisenbies. Optimization of harvest and logistics for multiple lignocellulosic biomass feedstock in the Northeastern United States." To be submitted to Energy.

Wang, Yuxi, J. Wang, J. Schuler, and D. Hartley. "Facility Siting Optimization for Biomass Energy Production in the Northeastern United States". To be submitted to Biomass & Bioenergy.

# Publications, Patents, Presentations, Awards, and Commercialization

Presentations

- Ebadian, M., Shedden, M.E., Webb, E., Sokhansanj, S., Eisenbies, M., Volk, T., Heavey, J., Hallen, K., 2017. Impact of parcel size, field shape, crop yield, storage location and collection equipment on the performance of single-pass cut-and-chip harvest system in commercial shrub willow fields. ASABE conference, Detroit, July 29-August 1, 2018.
- Ebadian, M., Shedden, M.E., Webb, E., Sokhansanj, S., Eisenbies, M., Volk, T., Heavey, J., Hallen, K., 2017. Improve harvest and collection efficiencies for willow and poplar plantations. Spokane, 2017.
- 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
- 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
- O. Therasme, M. Eisenbies, T.A. Volk, (July 23-25, 2018), Cover Protection Affects Fuel Quality and Natural Drying of Mixed Leaf-on Willow and Poplar Woodchip Piles, Woody Crops International Conference, Rhinelander, WI (Oral Presentation);
- O. Therasme, M. Eisenbies, T.A. Volk, 2017, Effect of Protection System on the Natural Drying and Fuel Quality in Willow and Poplar Chip Storage Piles, MABEX, State College, PA (Poster Presentation);
- O. Therasme, M.O. Fortier, T. A. Volk and T. Amidon, (October 28th, 2018), Willow Biomass as a Feedstock for Biorefinery: Evaluation of Bark Effect on Hot Water Extraction, and Lifecycle greenhouse gas emissions of Cellulosic Ethanol Production, American Institute for Chemical Engineering (AIChE), Annual Meeting, Pittsburgh, PA (Oral Presentation);
- O. Therasme, M.O. Fortier, T. A. Volk and T. Amidon, 2016, Life Cycle Greenhouse Gas Emissions of Ethanol Production from Willow, American Institute for Chemical Engineering (AIChE), annual meeting, San Francisco, CA (Poster Presentation)

# Publications, Patents, Presentations, Awards, and Commercialization

Presentations

- Shedden, M.E., Ebadian, M., Webb, E., Sokhansanj, S., Eisenbies, M., Volk, T., Heavey, J., Hallen, K., 2018. Operational reliability and its impact on harvest cost for woody crops. ASABE conference, Detroit, July 29-August 1, 2018.
- 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)
- T.A. Volk, S. Yang, M.O. Fortier, O. Therasme, (July 2018) Greenhouse Gas and Energy Balance of Willow Biomass Crops are Impacted by Prior Land Use and Distance From End Users, Woody Crops International Conference, Rhinelander, WI (Oral Presentation);
- Vance, John, Wang Jingxin, Shawn Crushecky, and Joseph Moritz. 2018. “Analysis of Mixed Hardwood Chipping Operations and Chip Quality for Bioenergy” presented at the Council on Forest Engineering, Williamsburg, Virginia, July.
- 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)
- Wang, Jingxin, Yuxi Wang, Damon Hartley, and Jamie Schuler.2018. “Optimization of Multiple Biomass Feedstock Supply Chains in the Northeastern United States.” Presented at 6th International Forest Engineering Conference, Rotorua, NZ, April.
- Wang, Jingxin,Yuxi Wang, Damon Hartley, and Jamie Schuler, Mark Eisenbies, Timothy A. Volk. 2018. “Multiple Biomass Feedstock Supply Chains in the Northeastern United States” presented at FORMEC (Forestry Mechanization) meeting, Madrid, Spain, September.
- Wang, Jingxin. 2018. “Hybrid Willow Derived Activated Carbon for Shale Gas Fracking Water Purification” presented at presented at 4th International Congress on Planted Forests, Beijing, China, October.
- Wang, Yuxi, Jingxin Wang, John Vance, and Zhang Xufeng. 2018. “Integrated Techno-Economic and Environmental Evaluation of Biomass-Based Value-Added Carbon Production.” presented at the Council on Forest Engineering, Williamsburg, Virginia, July.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# Responses to Previous Reviewers' Comments

2017 Peer Review Comments and Responses

Microsoft Word Document

2017 Go/NoGo Comments and Responses

Microsoft Word Document

# 3 – Task 3- Preprocessing and Blending (INL)

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

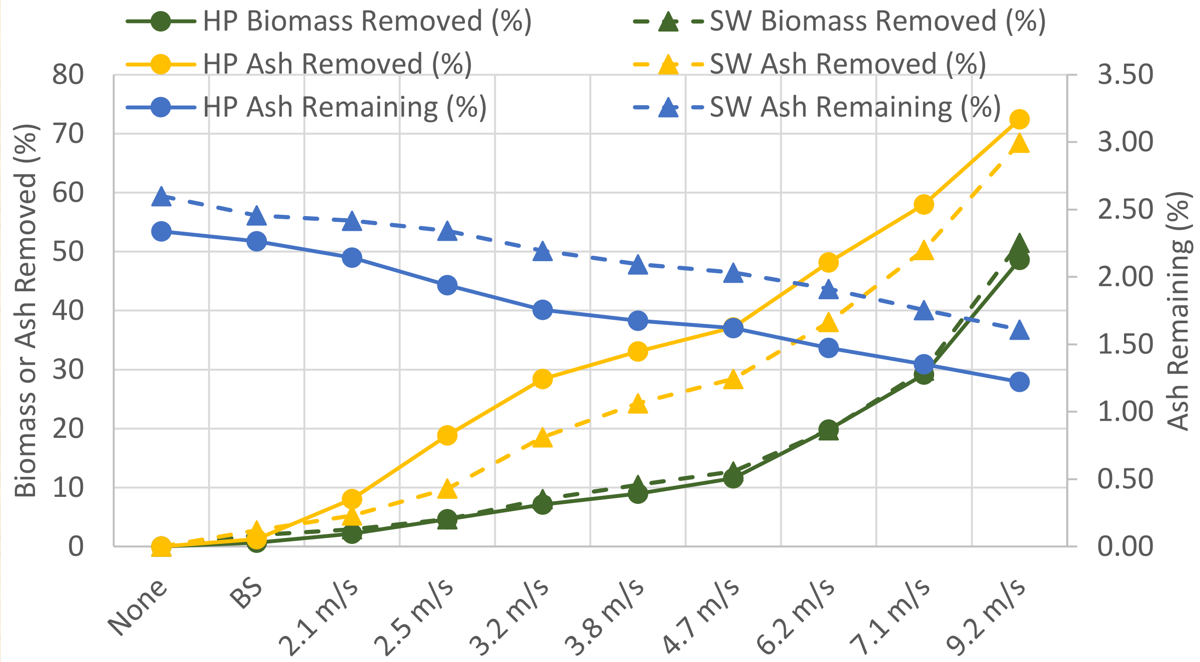
Top Figure:

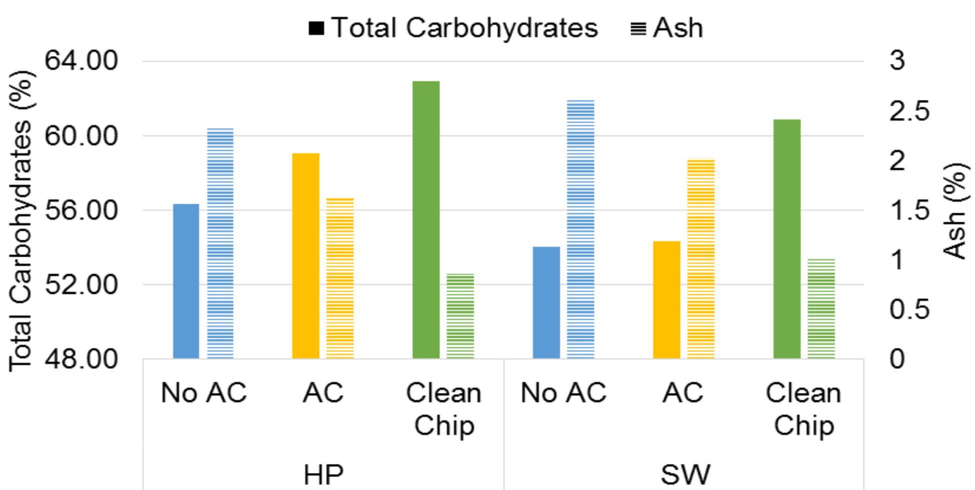
- Air classification removed leaves and reduced ash

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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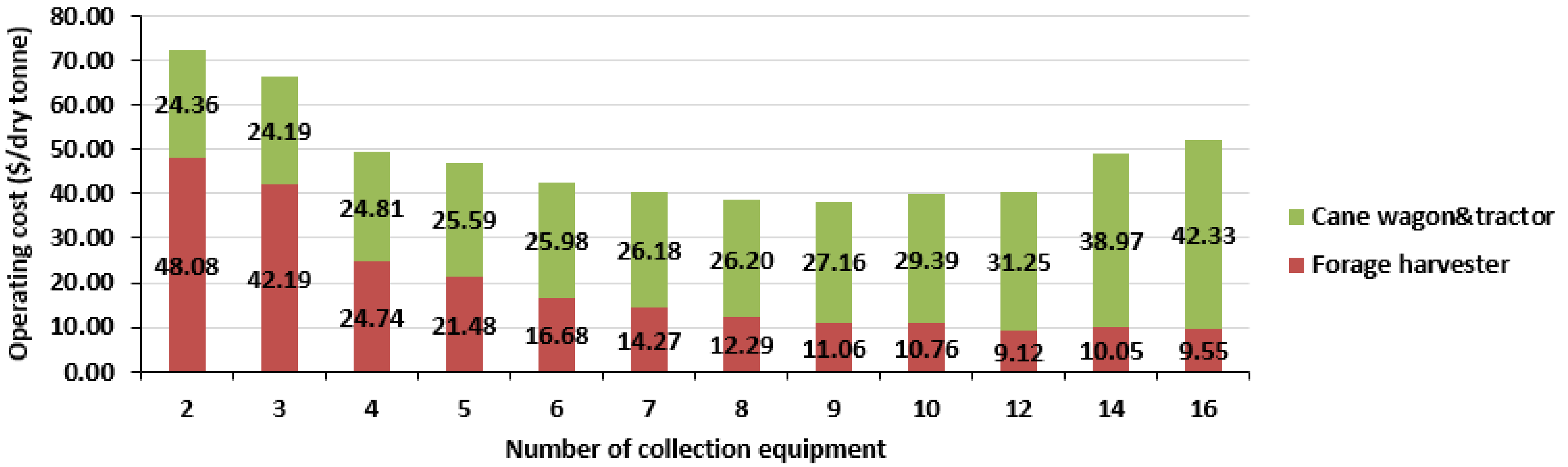
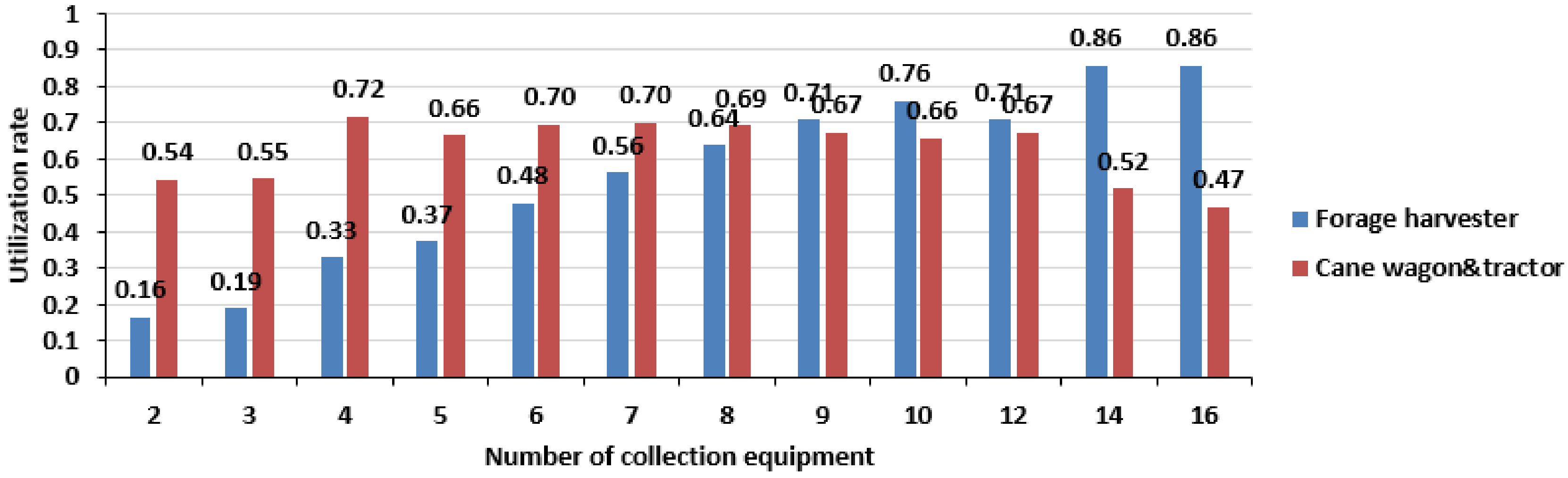
# 3 – Task 5- Logistic and Economic Modeling (ORNL)

- **Costs and utilization rate for 100 ha willow field harvest using IBSAL**

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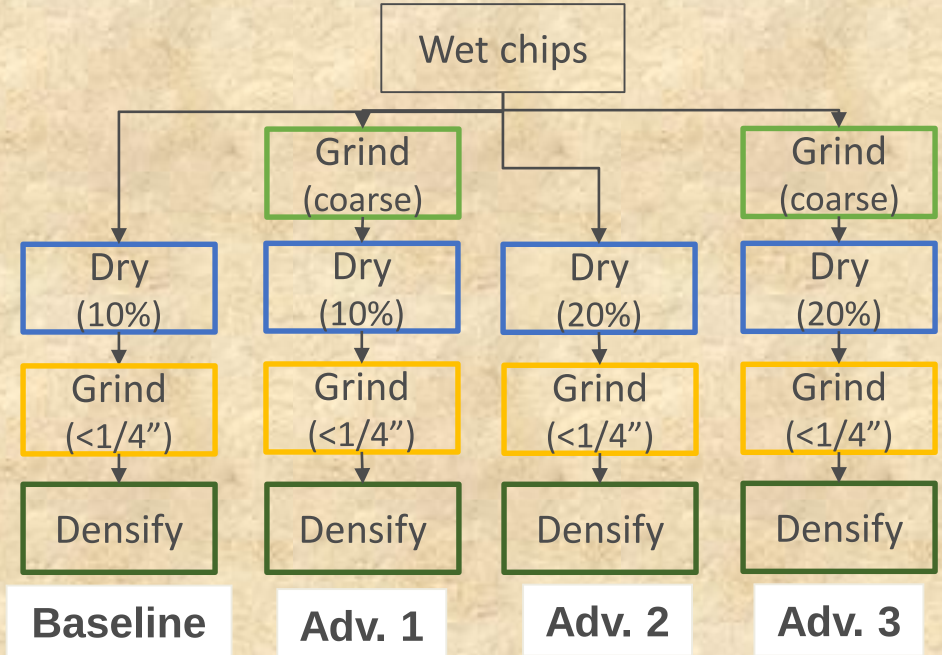
# 3 – Task 5- Logistic and Economic Modeling (INL)




## Shrub Willow ($/dry ton)

| | Baseline | Adv. 2 | Adv. 3 |
|---|---|---|---|
| Conveyance | 0.11 | 0.11 | 0.11 |
| Grinder 1 | -- | -- | 14.91 |
| Dryer | 24.35 | 23.29 | 20.11 |
| Grinder 2 | 14.35 | 10.67 | 15.59 |
| Densifier | 7.66 | 7.50 | 7.48 |
| Surge Bin | 0.03 | 0.01 | 0.01 |
| Dust Collection | 1.03 | 0.76 | 0.76 |
| **Total** | **47.25** | **42.34** | **58.97** |

## Hybrid Poplar ($/dry ton)

| | Baseline | Adv. 1 | Adv. 2 | Adv. 3 |
|---|---|---|---|---|
| Conveyance | 0.15 | 0.15 | 0.14 | 0.14 |
| Grinder 1 | -- | 15.16 | -- | 15.16 |
| Dryer | 44.69 | 25.89 | 20.28 | 17.83 |
| Grinder 2 | 15.29 | 13.81 | 10.58 | 15.18 |
| Densifier | 8.04 | 7.92 | 8.23 | 8.23 |
| Surge Bin | 0.03 | 0.03 | 0.03 | 0.03 |
| Dust Collection | 1.06 | 1.06 | 1.06 | 1.06 |
| **Total** | **135.30** | **117.73** | **94.03** | **111.34** |

- Drying is most expensive operation
- High moisture densification (Adv. 2) had the lowest processing costs
- Advanced strategies will contribute to integrated supply chain models' goal of demonstrating a decrease in feedstock delivery cost by $2/dry ton