Feedstock Logistics and Preprocessing R&D at INL

Lynn M. Wendt, Ph.D.
Bioenergy Program Lead
Idaho National Laboratory

November 17, 2021
CAAFI Webinar

Idaho National Laboratory

INL's Biomass Feedstock National User Facility

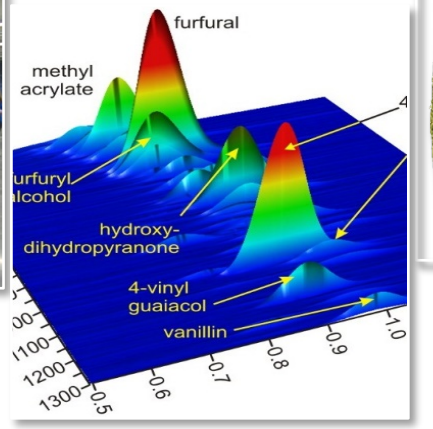
Feedstock logistics, preprocessing, and modeling capabilities spanning bioenergy supply chain

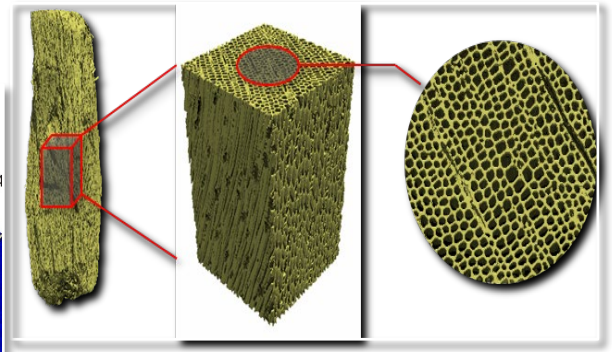
Feedstock Supply & Logistics
- Integrated landscape management
- Resource mobilization
- Techno-economic and life cycle assessments

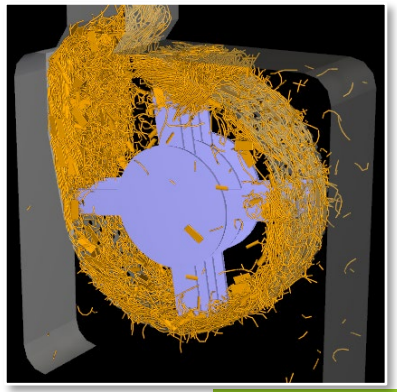
Biomass and MSW Variability Management
- Feedstock characterization
- Interfacial property measurement
- Post-harvest physiology & chemistry solutions

Mechanical Preprocessing R&D
- Bench to pilot scale preprocessing and fractionation
- Artificial intelligence-based materials preprocessing

Scale-up for Conversion-Ready Feedstocks
- Testing, development, and scale-up of preprocessing technologies
- Computational modeling and digital twins for rapid scale-up



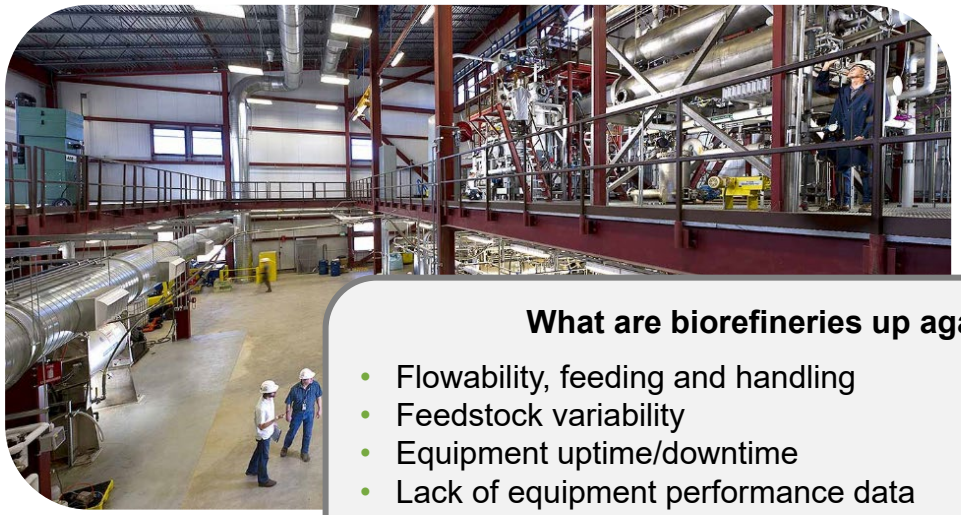




Feedstock Supply Chain Challenges

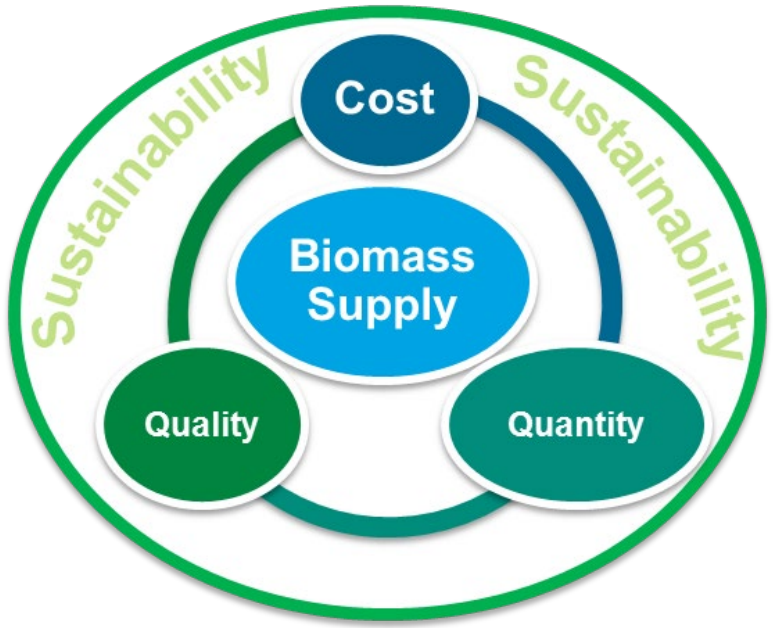
Feedstock Supply and Logistics | *Preprocessing* | *Conversion*

Production → Harvest & Collection → Long-Term Storage → Transportation → Short-Term Storage & Queuing → Size Reduction & Pelleting → Pretreatment → Enzymatic Hydrolysis → Conversion of sugar monomers to fuels/chemicals

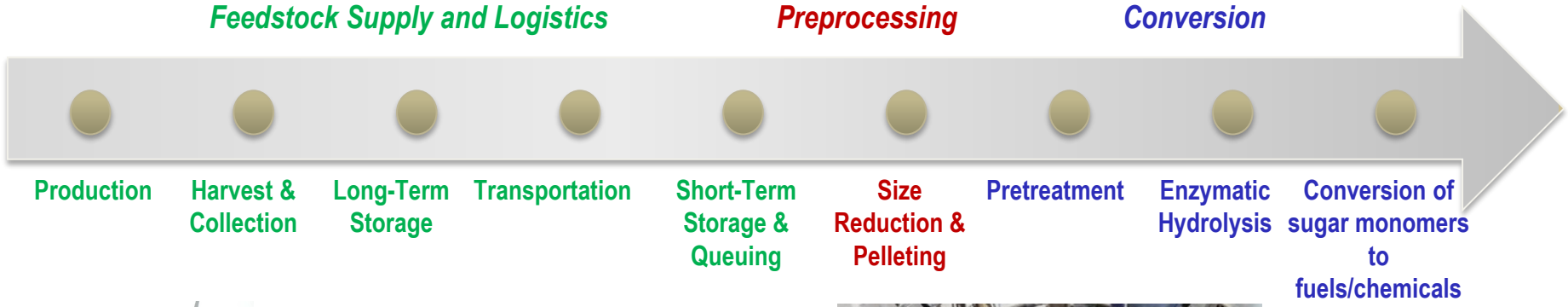


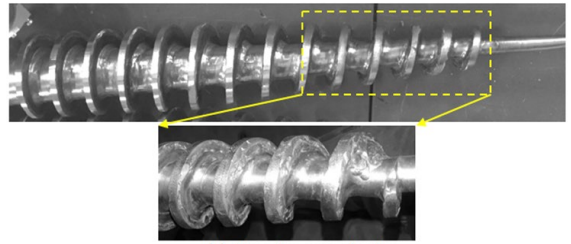
What are biorefineries up against?

- Flowability, feeding and handling
- Feedstock variability
- Equipment uptime/downtime
- Lack of equipment performance data
- Lack of feedstock specifications

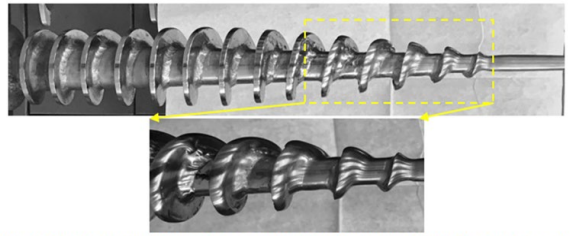


Feedstock Supply Chain Challenges





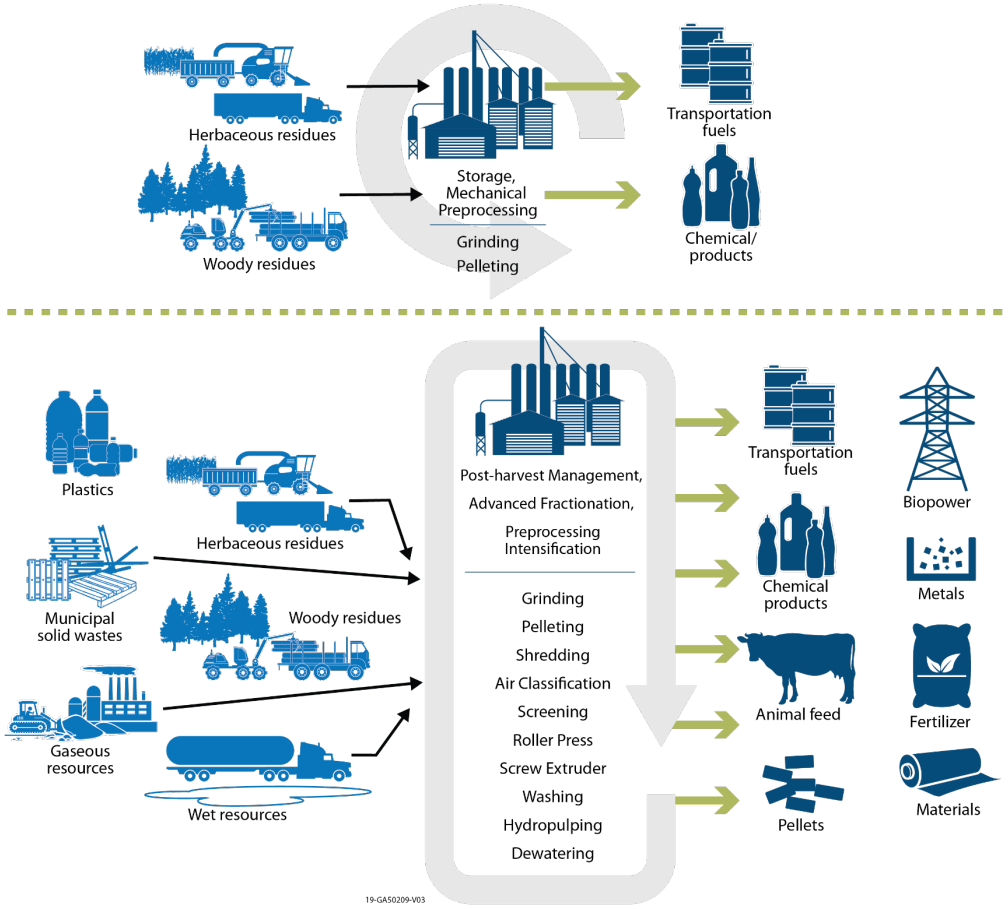
(a) New plug screw feeder



(b) Worn plug screw feeder after merely 54 hrs of operation with high-ash corn stover

Updated Vision: Quality-by-Design Feedstock Supply Chain

- Develop value-add, transformative, economical and sustainable technologies to enable Quality-by-Design Feedstock Supply Systems from renewable and diverse carbon and energy sources for biofuels, bioproducts and biopower production



Uniform Format Feedstock Supply System

Stone Milling Approach

Simple supply systems that grinds, dries and densifies

Quality-by-Design Feedstock Supply System

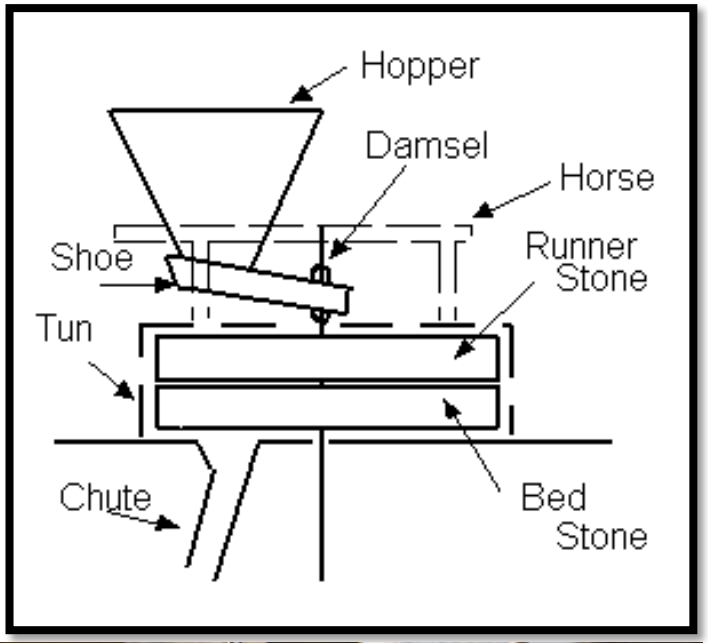
Fractional Roller Milling Approach

Expands preprocessing operations:

- Enables access to new feedstocks
- Selective pairing of feedstock fractions and conversion processes based on feedstock quality
- **Midstream** for fractionation, merchandising, and value-add

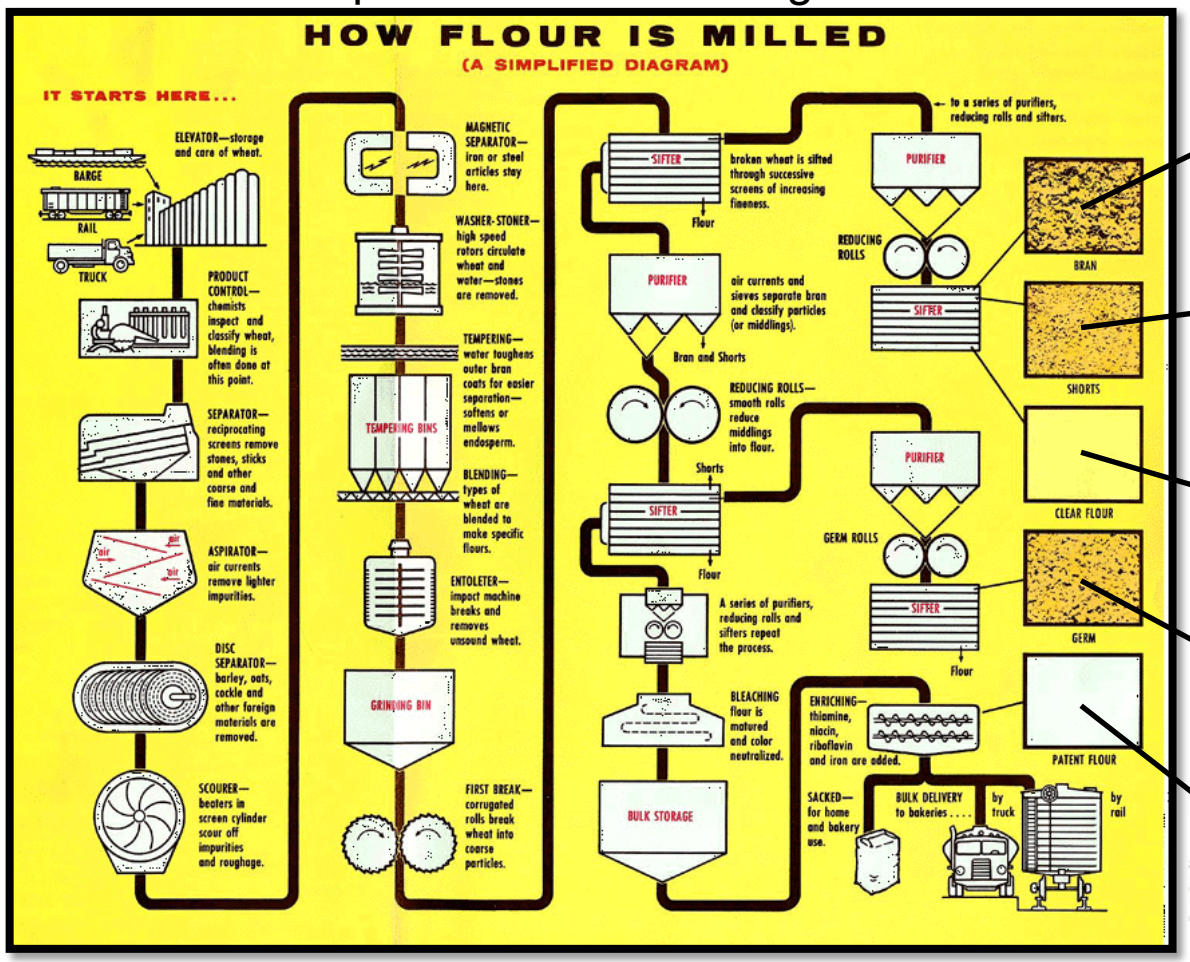
Accelerating the Process of Innovation

Grist Mill Diagram



Whole Wheat Stone Milled Flour

Simplified Roller Mill Diagram



Bran

Shorts

Clear Flour

Germ

Patent Flour

Quality is an Issue for all Biomass Resources

Forest Residues

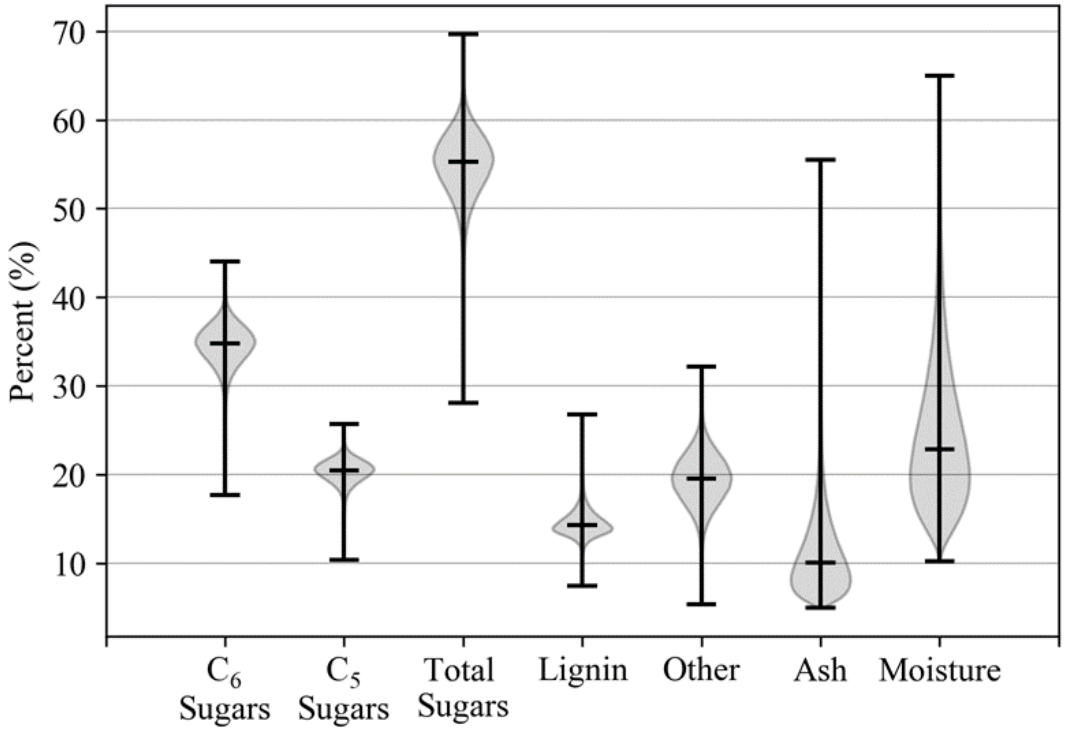
Corn Stover Bales

Municipal Solid Waste

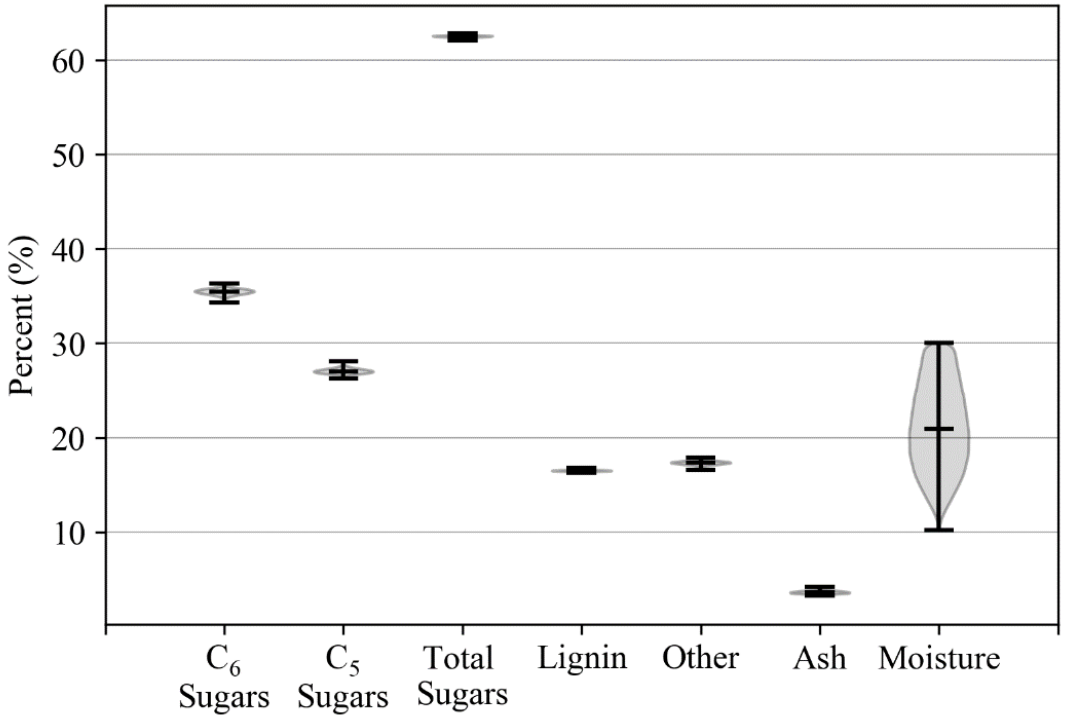
- Raw Biomass DOES NOT meet Feedstock Specifications
- Biomass Resource Diversity and Variability Requires Preprocessing of Raw Biomass to Achieve Feedstock Specification

Less than 30% of Field-Run Corn Stover Meets Critical Biorefinery Quality Specifications

Field-Run Stover Quality Variability

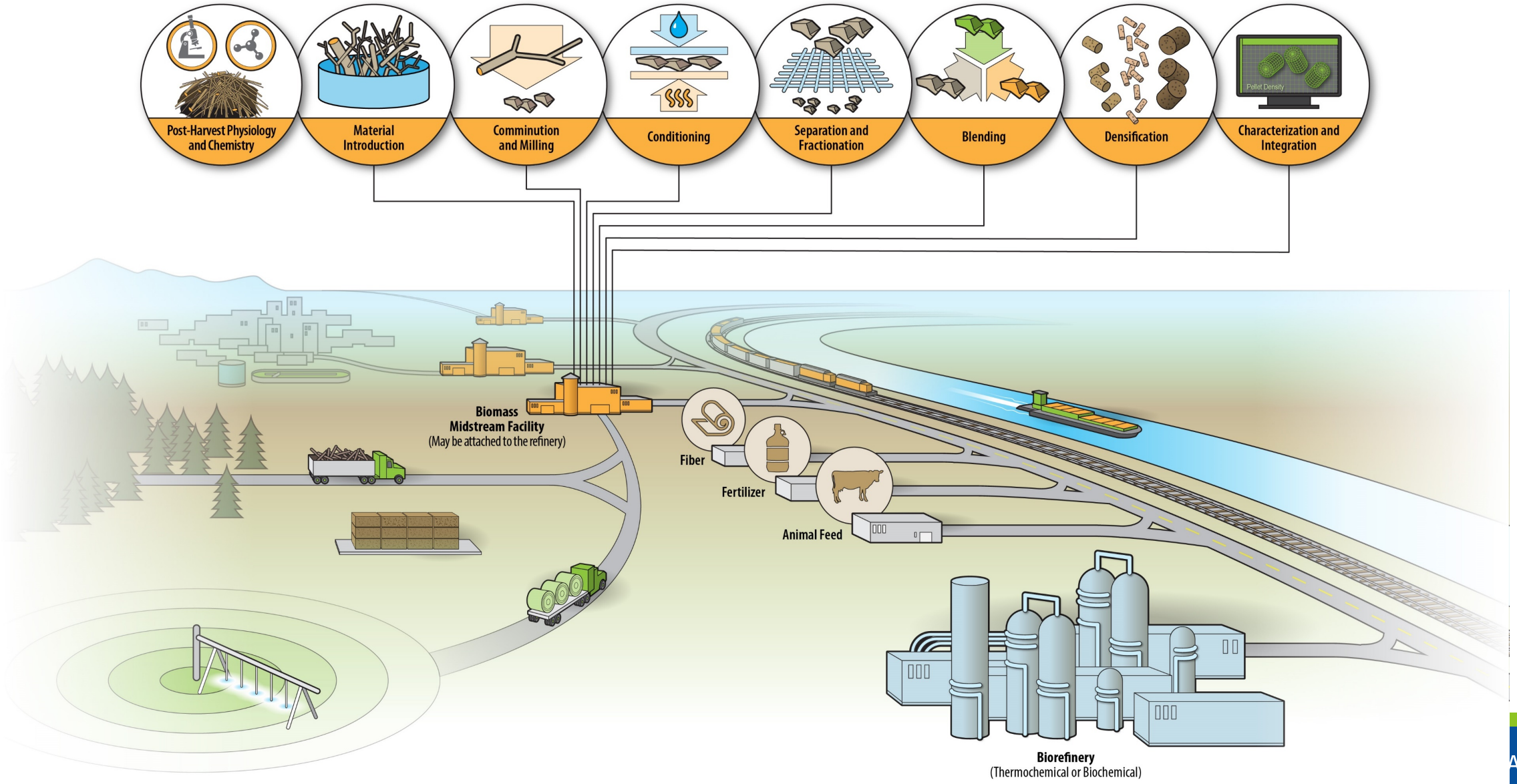


Biorefinery Feedstock Quality Specs



- Greater than 90% of Biomass Feedstock material must meet all conversion specifications

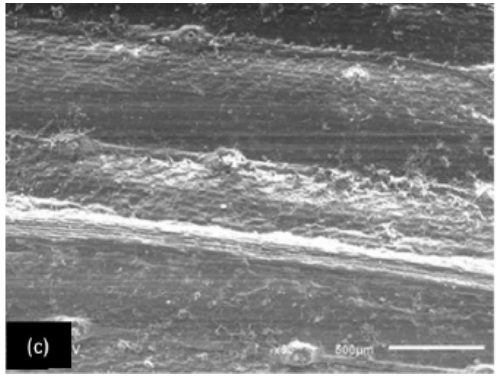
Fractional Milling, Separation, Formulation, and Merchandising



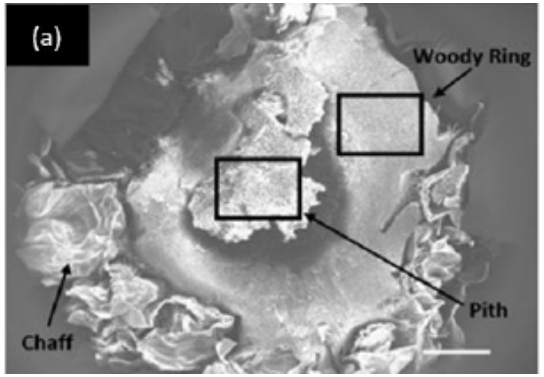
Variability is Inherent to Herbaceous Biomass

- Anatomical Fractions have variable response in mechanical and chemical processing
  - Leaves are pulverized upon impact
  - Husks and stalk need shear-based size reduction

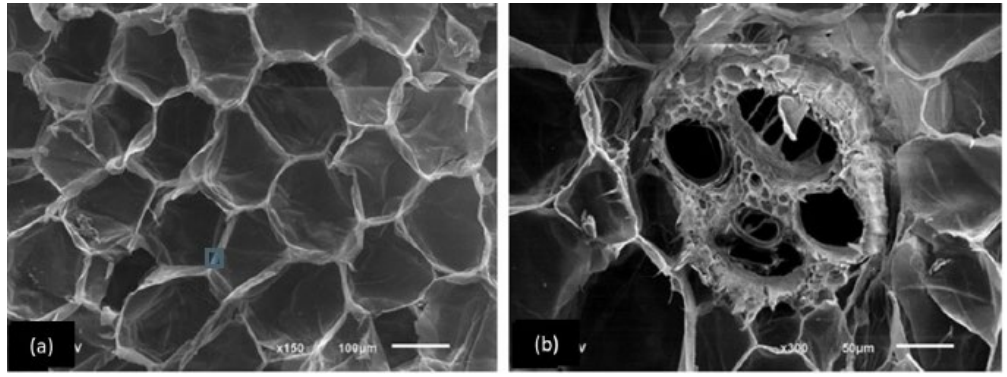
Li et al., 2020, *ACS Sus. Chem. Eng*



Corn stover leaves



Corn cobs



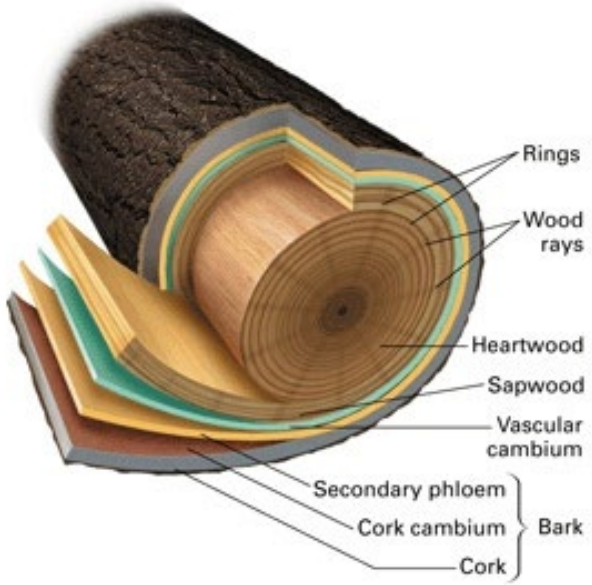
Corn stover stalks

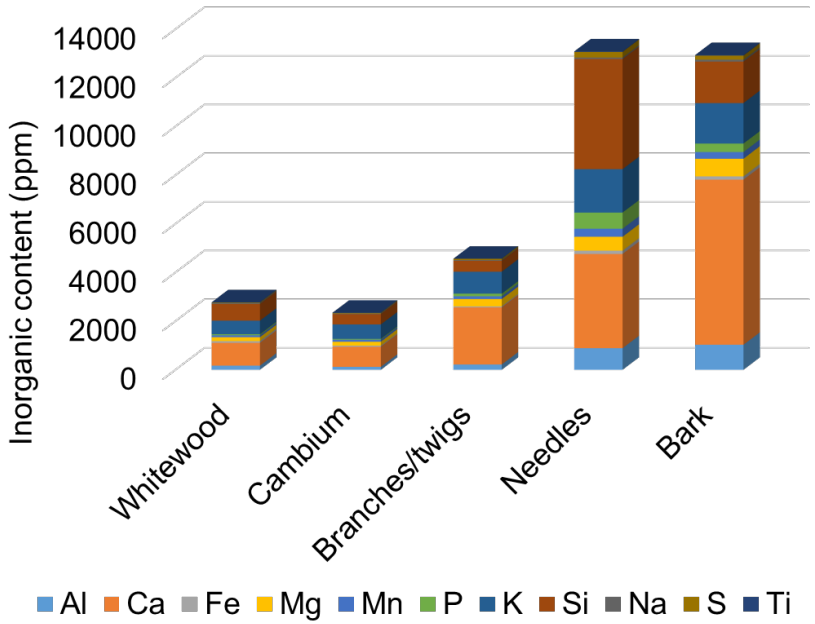
Reconfigurable Fractional Milling Loop

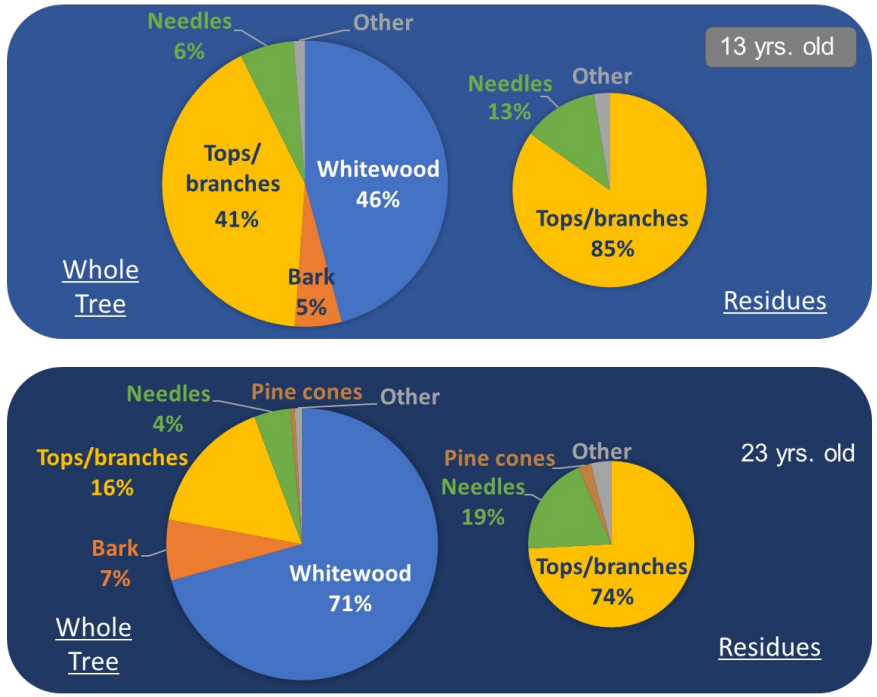
- Multi-stage comminution and separations enables fractionation
  - Removal of soil
  - Separation of husks and leaves
  - Recycle to achieve a narrow size distribution

- Reconfiguration enables tailored fractionation for multiple feedstocks and conversion pathways

Anatomical Fractionation is Critical to Achieve Conversion Specifications







- **Wood has many anatomical fractions with significant differences ash concentration**
  - Inorganics are responsible for slagging and fouling of catalysts in conversion
- The needles and bark (contained in the tops/branches) contain the most ash and their content changes with age

Multi-Stage Comminution Combined with Separators Enables Pine Residue Fractionation

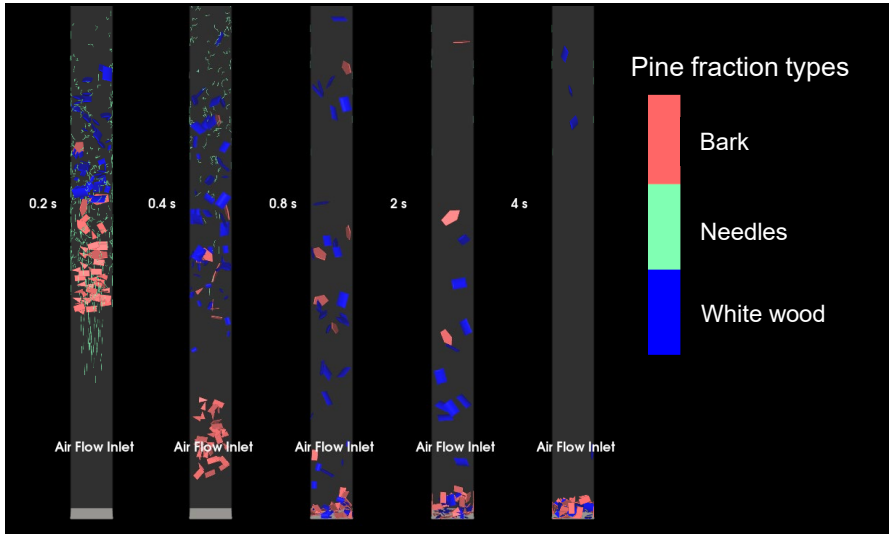
Forest Residue

White Wood

Bark

Needles

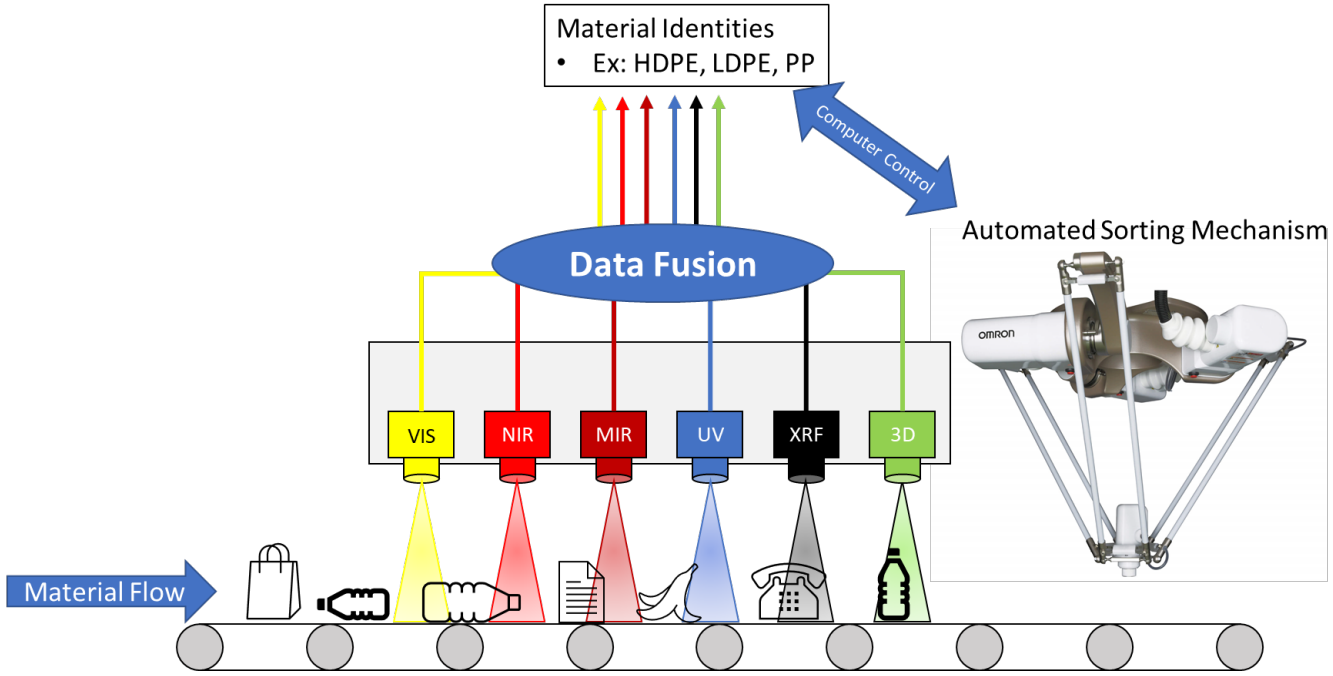
Forest residues can now be **separated into almost pure anatomical fractions** that will **reduce fines generation** and energy consumption in downstream milling operations



Physics-based computational models are used to build comminution and fractionation digital twins

Developing Over-Belt Technologies for Separations and Material Characterization

- Separations and Sorting Vision Systems
  - Artificial Intelligence/Machine Learning powered systems



Summary

- INL's capabilities range from feedstock logistics, preprocessing, and modeling spanning bioenergy supply chain
  - Biomass Feedstock National User Facility designated in 2013
- Feedstock quality specifications are critical to maximizing predictability of conversion
- As industry moves to more diverse resources such as MSW, wet wastes, and gaseous feedstocks to support a circular carbon economy, more emphasis is needed to reduce variability in:
  - Flowability and Handling
  - Fractionation (critical to maximizing revenue)
  - Stability
- **Feedstock management is critical to biorefinery performance**

Acknowledgments

- This work is supported by the U.S. Department of Energy's Office of Energy Efficiency & Renewable Energy, Bioenergy Technologies Office, under DOE Idaho Operations Office Contract DE-AC07-05ID14517.

Contact Information:

Lynn Wendt, Ph.D.

Idaho National Laboratory

Lynn.Wendt@inl.gov

https://www.linkedin.com/in/lynn-wendt-13292721b