10-8-2019

# Feedstock Supply and Logistics Research & Development

Chenlin Li, PhD

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Oct 8, 2019
Montana DOE National Lab Day Meeting


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Idaho National Laboratory

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

## *Vision: A System Capable of Supplying Conversion-Ready Biomass Feedstock*

The Uniform Commodity Feedstock Vision enables commodity-scale, custom-formulated feedstocks to play a critical role in producing biofuels, biopower, and other bioproducts.

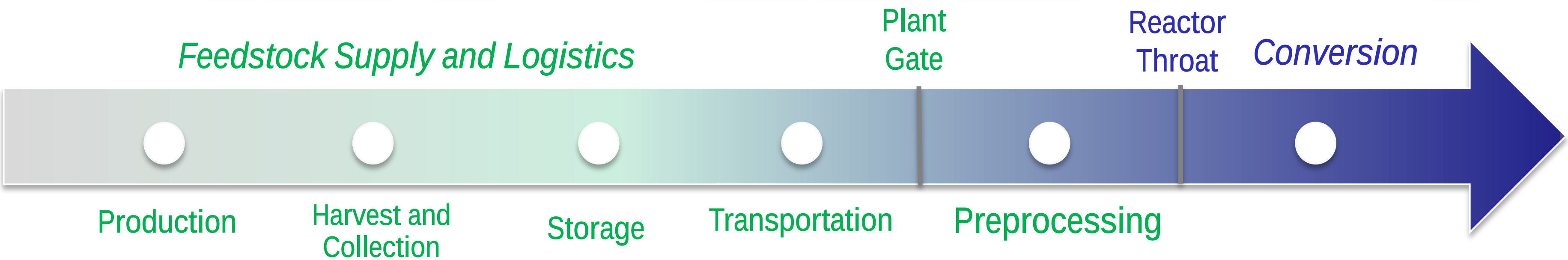

### Biomass Preprocessing

Biomass preprocessing, which transforms biomass into feedstock, is key to a commodity bioenergy vision. A preprocessing depot can provide a link between biomass producers and refineries. It also alows flexibility for local communities to produce bioproducts including feedstocks customized for biochemical, thermochemical, and combustion conversion facilities. It also enables production of renewable products, such as livestock feeds, and recycled byproducts, such as soil amendments.

The Preprocessing Depot enables development of commodity biomass feedstock markets by managing diverse biomass, promoting increased resource access, and ensuring quality, on-spec feedstock delivery to conversion facilities.

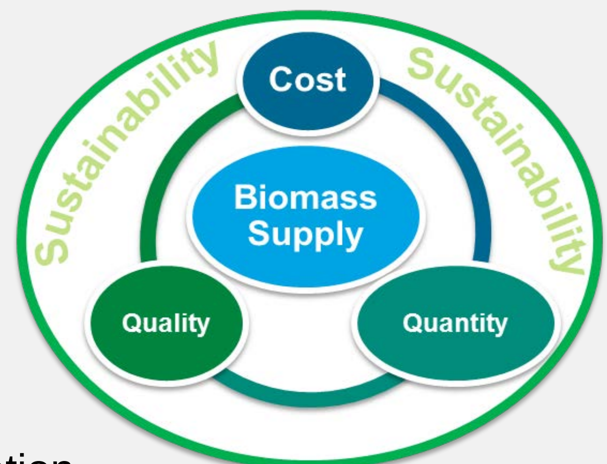
But a preprocessing depot can do much more. It offers limitless opportunities for innovations to supply entirely new products and markets.

# Feedstock Supply Chain Challenges



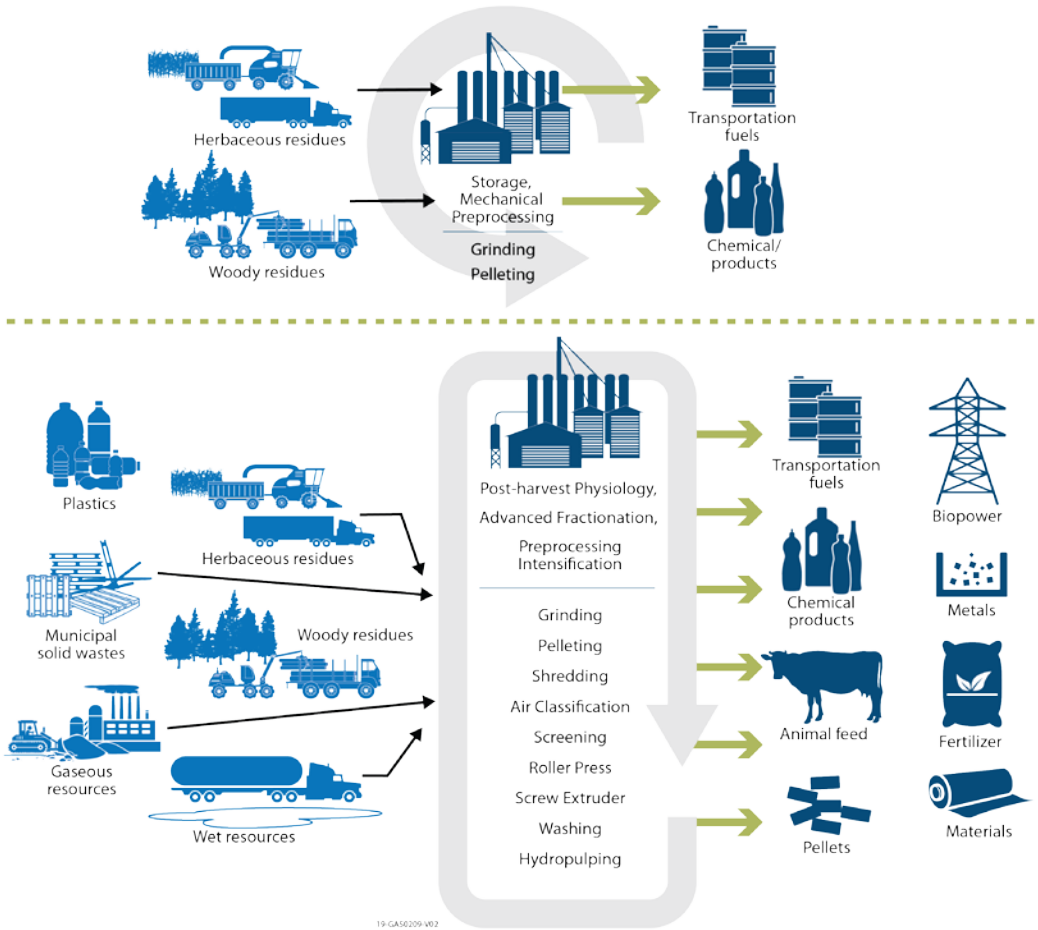

## INL Feedstock R&D Focus Areas:

- Post Harvest Physiology and Chemistry
- Advanced Preprocessing and Fractionation
- Feedstock-Conversion Interface Consortium
- Bench to Engineering Scale R&D Development and Verification
- Feedstock Supply Chain Cross-Cutting Analysis and Sustainability



## *Changing the Paradigm from Cost to Value Using Fundamental Principles*

**Cost-Centered Feedstock Logistics Supply System**




**Revenue-Centered Feedstock Logistics Supply**

- Bottleneck is present due to a “one-size fits all” preprocessing approach used for multiple feedstocks and multiple conversion processes
- Expanding preprocessing operations provides multiple high- and low-value streams

# *Post-Harvest Physiology—Value Add*


Transforming storage from a cost-center to a value-add operation

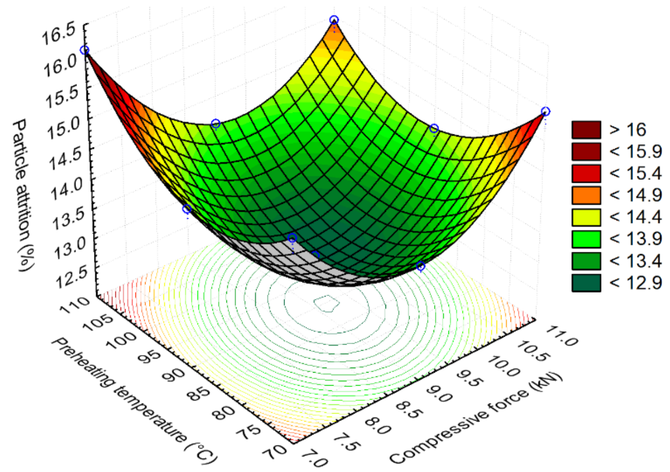
- Moisture management through engineered systems
  - Manage self-heating/coupled drying, pH shifts, and oxygen availability
- Control shrink by reducing $CO_2$ evolution
  - Redirecting metabolic function of communities
  - Developing models to predict degradation based on environmental factors
- Reducing recalcitrance
  - Collaborative efforts underway with NREL Algae and Conversion groups to assess downstream performance
  - Benefits observed in corn stover and algae

# *Preprocessing – Size Reduction, Drying and Densification*

Breakthrough: Identified the root cause and reduced biomass particle attrition (generation of fines) during grinding and pelleting process.

**Progression of particle attrition targets reduction**

| | FY-17 (current value in pellets produced using conventional method) | FY-18 | FY19 (go-no-go) | FY-19 | FY-20 |
|---|---|---|---|---|---|
| Particle attrition targets (%) | 35-38 | 21 | 14 | 10.5 | 7 |




Particle attrition caused by compression force and preheating temperature

Optimization of the pelleting process conditions and feedstock properties results in particle attrition values <14 % in the pelleted feedstock.

Optimized process conditions to minimize the attrition

| | **Optimized pelleting process conditions** | **Predicted attrition (%)** | **go-no-go target** |
|---|---|---|---|
| **Hammer mill screen size (inch)** | 7/16 | 11.94 | <14 |
| **Moisture content (%, w.b.)** | 19.93 | | |
| **Compressive force (kN)** | 9 | | |
| **Preheating temperature (°C)** | 91.23 | | |
| **Residence time (sec)** | 45 | | |

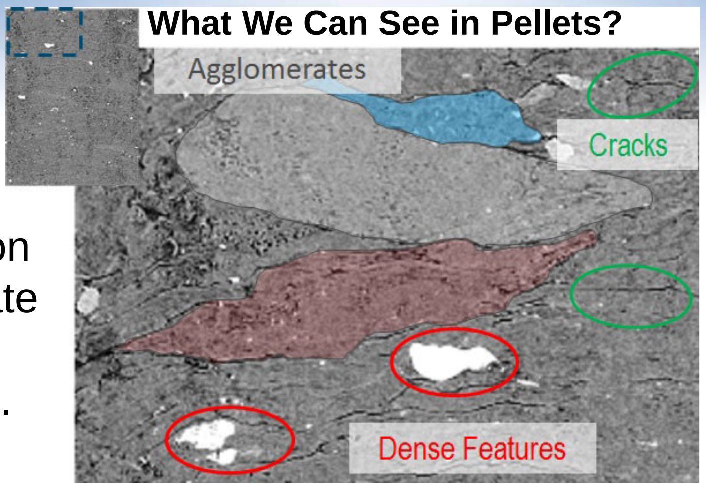
# *Advanced Characterization of Pellets*

## Pellet characterization studies

**CT-scan:** X-ray CT provides **3D non-destructive** images of pellets and enables spatial and morphological characterization without destroying pellet. Helps to understand the agglomerate size and surface area of the pellet particles.

**Focused Ion Beam Tomography**: 3D analysis of the pellets. Helps to understand the material flow in the pellet die and in turn the microstructure formation.

**Energy-dispersive X-ray spectroscopy (EDS) Mapping:** Quantification of carbon, silicon and oxygen distribution in the pellet.

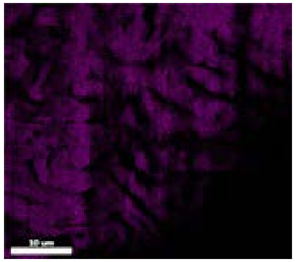



**CT-scan of a pellet**

**Primary Features Extracted:**

Cracks, Dense Features and Agglomerates

**EDS mapping of pellet**



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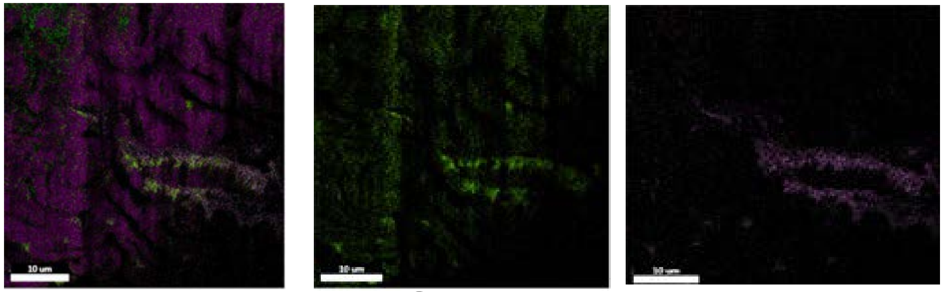
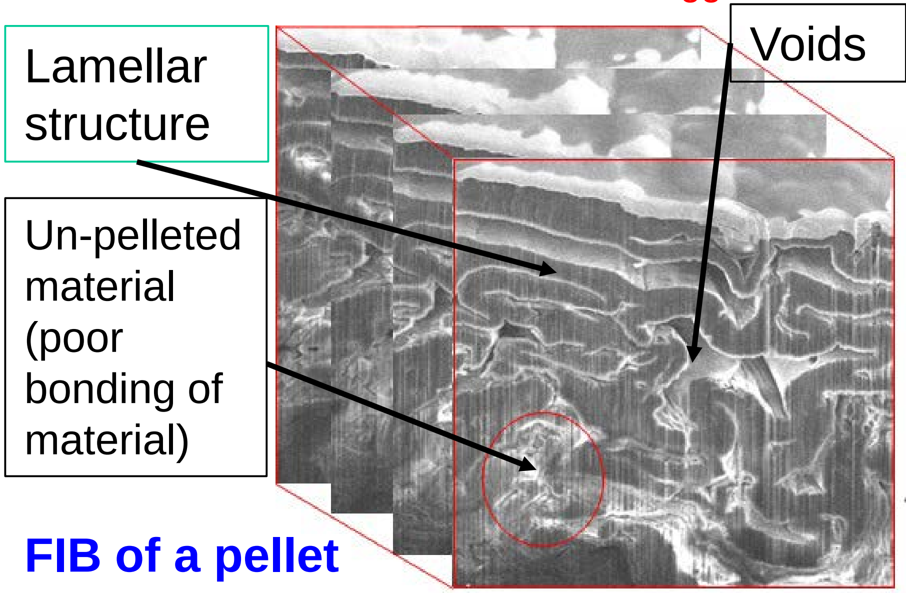


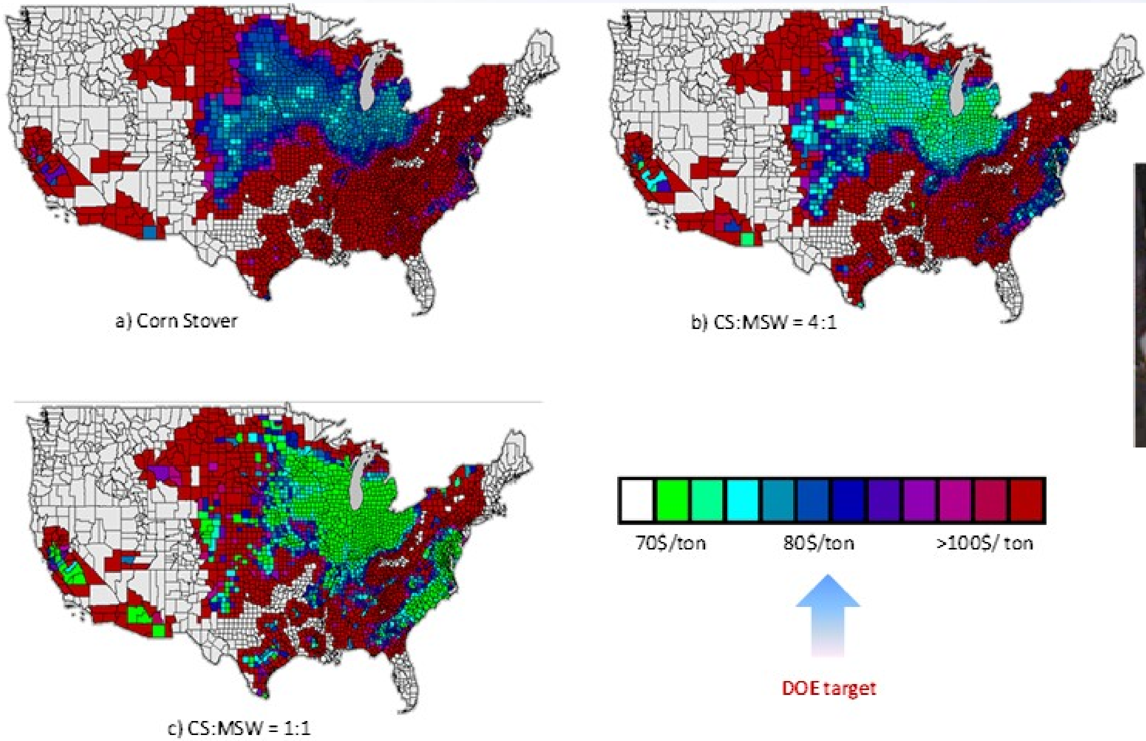
O

Si




**FIB of a pellet**

# *Low-Cost MSW for Preprocessing and Formulation*




**Non-recyclable paper**

MSW/CS blends show the great potential to meet the “cost target”

| CS/MSW ratio | Ash (%) | Glucan (%) | Xylan (%) | Glucan+Xylan (%) |
|---|---|---|---|---|
| **10:0** | 3.0 | 33.2 | 20.8 | 50.8 |
| **9:1** | 3.8 | 35.5 | 19.7 | 55.2 |
| **8:2** | 4.6 | 37.7 | 18.6 | 56.3 |
| **7:3** | 5.4 | 40.0 | 17.6 | 57.6 |
| **6:4** | 6.2 | 42.2 | 16.5 | 58.7 |
| **5:5** | 7.0 | 44.5 | 15.4 | 59.9 |
| **0:10** | 10.9 | 50.8 | 10.0 | 60.8 |

MSW/CS blends show the great potential to meet “quality requirements” for conversion


J Yan, et al., 2019. ChemSusChem. Article in Press.
C Li, et al., 2017. Biotechnology for Biofuels. DOI 10.1186/s13068-016-0694-8
L Liang, et al., 2017. RSC Advances. DOI: 10.1039/c7ra06701a rsc.li/rsc-advances
N Sun, et al., 2015. Bioresource Technology.doi.org/10.1016/j.biortech.2015.02.087

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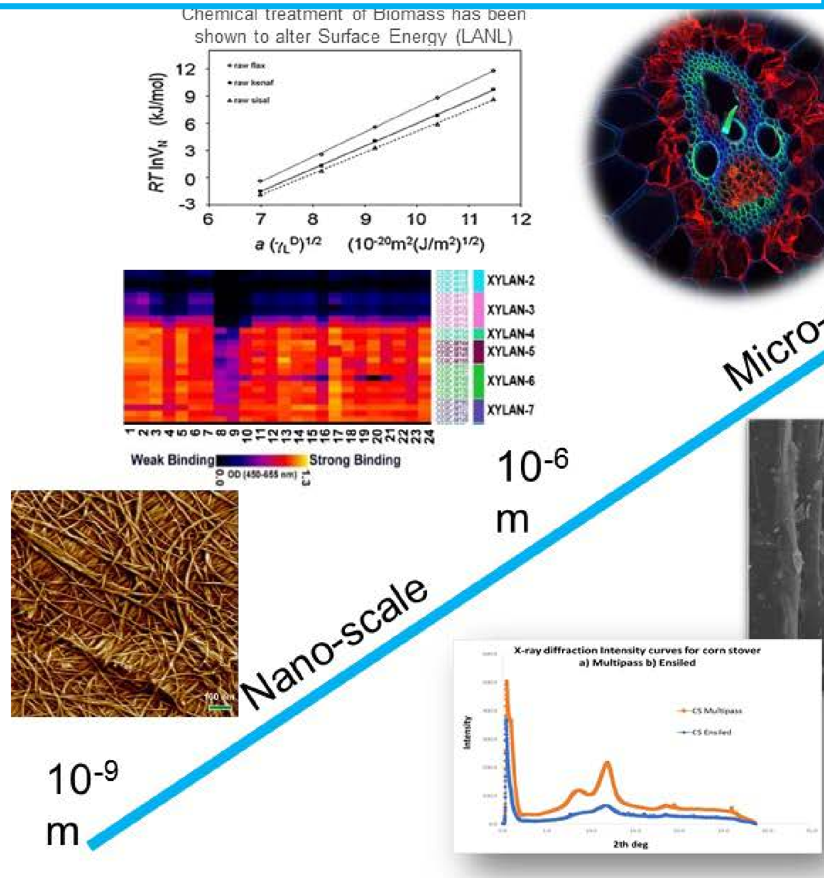
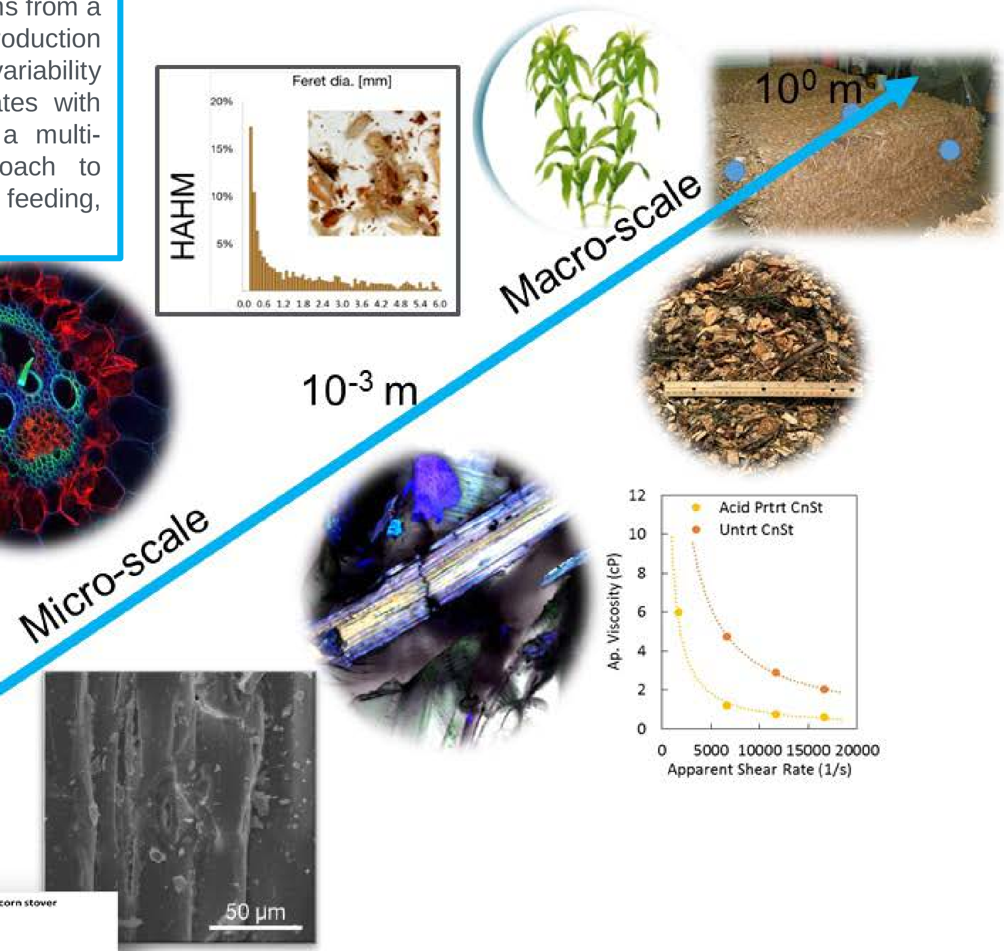
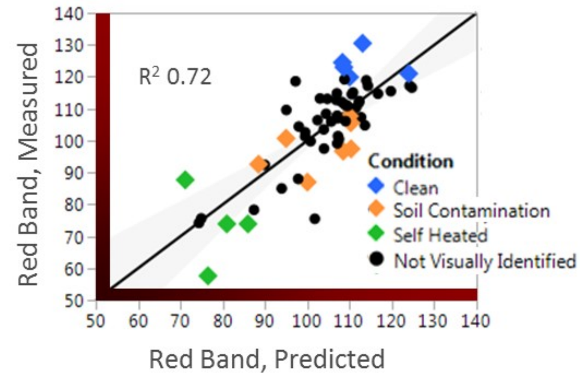
# *Feedstock-Conversion Interface Consortium - Multi-scale Characterization*

**Hypothesis:** Critical Material Attributes manifest at multiple-scales (from molecular to the macro-scale) with variability that stems from a myriad of sources (natural, intrinsic, growth factors and production operations). The sources and range of feedstock attribute variability is highest at the beginning of the process and propagates with modification through the system. Biomass variability is a multi-dimensional problem that requires a multi-scale approach to elucidate mechanisms by which attributes impact feeding, preprocessing, and conversion.



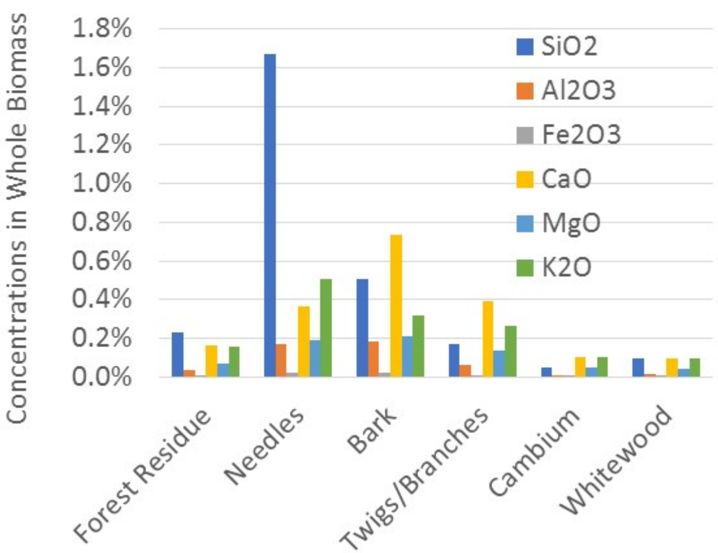



# FCIC –Characterization Tool Developed to Assess Quality & Variability


***FCIC — Task 2 Feedstock Variability***

**Highlight: rapid, simple, digital imaging approach developed and employed to provide quantitative analysis of bale 'quality'**




***Variability Identified at Anatomical Fractions Scale***

**Highlight:**

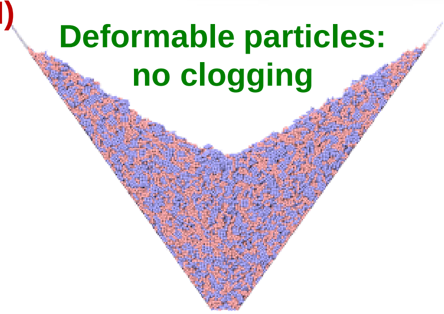
- Quantitation of inorganic species in anatomical fractions enables high-fidelity fractionation for targeted end use;
- Guides method development to discriminate between physiological and soil-derived, inorganic contaminants

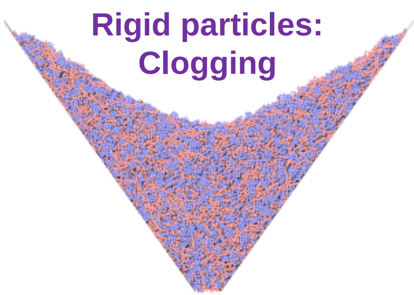
**https://bioenergylibrary.inl.gov/Home/Home.aspx**

**https://fcic.inl.gov/**

## FCIC – Biomass Flow Modeling Inform Behavior and Equipment Design

**Particle level Discrete element modeling (DEM)**

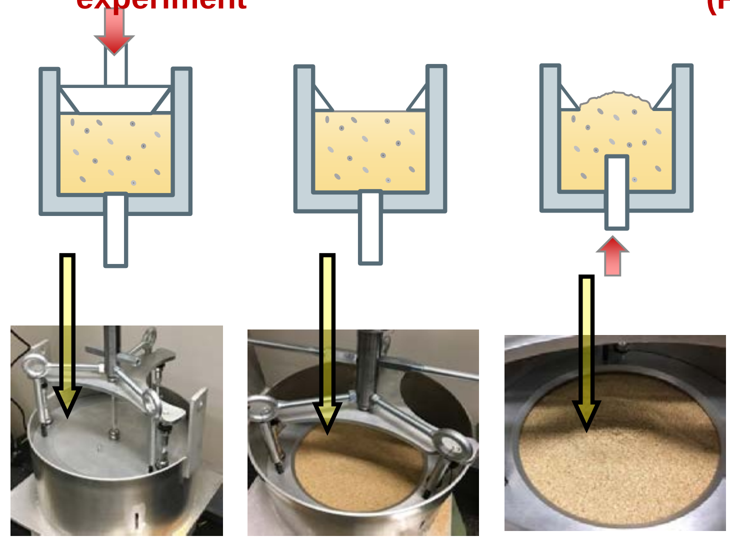



DEM simulation reveals biomass particle deformation is a critical factor (ignored in literature)

- *Improve understanding of fundamental physics of biomass flow*

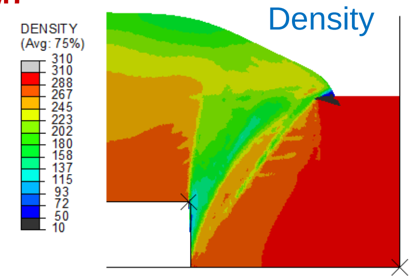
**Multi-scale characterization & experiment**

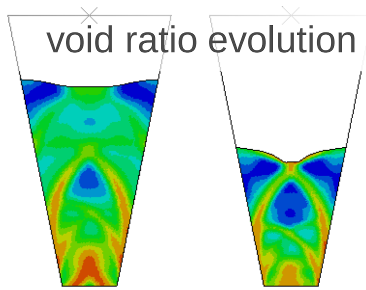


INL Customized Axial shear tester can identify more biomass properties (Comparing to standard equipment)

Model validation

**Bulk level Finite element modeling (FEM)**




FEM simulation reveals the capabilities and limitations of current advanced constitutive models for biomass.

- *Model reformulation*

**Development of Validated, Physics-based Constitutive Laws of Biomass Flow Behaviors**

**First-principles based equipment design tools for trouble-free feeding of feedstock**

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# Capabilities that Span the Biomass Supply Chain

**Production**

- Feedstock characterization (chemical, solid fuel properties)
- Pairing feedstock to pathways
- Storage
- Pellet properties

**Logistics**

- Techno-economic assessments

**Preprocessing**

- Independent testing, development, & scale-up of preprocessing technologies

**Conversion**

- Feedstock Supply
- Scale-up & integration of preprocessing systems
- Feedstock Feasibility Studies

**Feedstock Supply/Logistics Demonstration**

# ***Thank you!***

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