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WBS 1.2.3.3 Biomass - Feedstock User Facility

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Feedstock Supply and Logistics

Kevin L. Kenney

Idaho National Laboratory

Goal Statement

- The goal of this project is to engage industry collaborators in the scale-up and integration of biomass preprocessing systems and technologies that
  - Advance the achievement of BETO goals and mission AND
  - Advance the development and commercialization of biomass preprocessing systems that address the needs of the biofuels' and bioproducts' industries

Quad Chart Overview

Timeline

- Project start date: FY 2009
- Project end date: FY 2017

Budget

	Total Costs FY 2010 to FY 2012	FY 2013 Costs	FY 2014 Costs	Total Planned Funding (FY 2015 Project End Date)
DOE Funded	$9.1M	$2.5M	$2.0M	$6.0M
Project Cost Share (Comp.)*		$85k	$850k	$3.0M

Barriers

- Ft-E, Engineering Systems
- Ft-J, Biomass Material Properties
- Ft-K, Biomass Physical State Alteration

Partners

- Forest Concepts
- Vortex Processing
- UOP
- Ensyn
- DuPont
- Cool Planet
- TerraPower
- InnerPoint Energy
- Vermeer

1 - Project Overview

- FY 2009 to 2011: Design, Engineering, and Fabrication of Biomass Feedstock Process Demonstration Unit (PDU)
- FY 2012: Support of BETO FY 2012 Cellulosic Ethanol Demonstrations
  - Preprocessing demonstration
  - Feedstock supply for conversion demonstrations
- FY 2013:
  - Moved PDU from parking lot to 27,000-ft^2 high bay in the INL Energy Systems Laboratory
  - National User Facility designation in July 2013
  - Executed first User Facility Project with Forest Concepts and Vortex Processing
- User Facility funding designated to cost share collaborative projects
- FY 2014: Conducted four User Facility projects
  - 2 feedstock supply
  - 1 feedstock characterization
  - 1 scale-up and integration
- FY 2015: On track to double FY 2014 project count

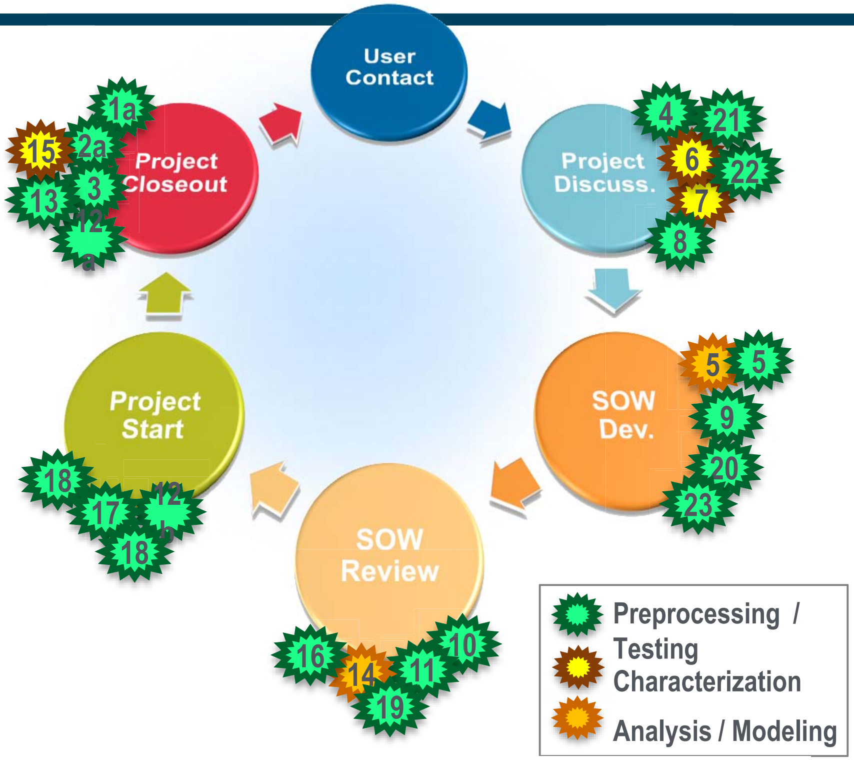
Biomass Feedstock Process Demonstration Unit (PDU)

2 – Approach (Technical)

- Biomass Preprocessing Scale-Up and Integration
  - Feedstock supply
  - Feedstock development (develop specs and preprocessing designs)
  - Technology RD&D
- Biomass Characterization
  - Resource characterization
  - Feedstock (product) characterization

2 – Approach (Management)

- **Project Scope**
  - Every project requires an external collaborator (industry, univ, federal)
  - Strive to parse out non-proprietary results from every project, including proprietary projects
  - Mix of directed/open projects
  - Proprietary projects pay 100%
  - Non-prop. projects require ~50% cost share
  - UF funds “facility readiness” for all
- **Management Tools**
  - DOE review/approval
  - New User Facility business tools
  - Customer relationship management, project develop process using SalesForce
  - Annual market assessments
  - Marketing/Trade-shows



- **Success Factors**
  - # projects
  - # users
  - # students
  - # publications
  - Customer feedback
- **Challenges**
  - Maintaining project pipeline
  - Working at the pace of industry
  - Hitting feedstock specs

3 – Technical Accomplishments

Since last peer review: transitioned from a project to a National User Facility

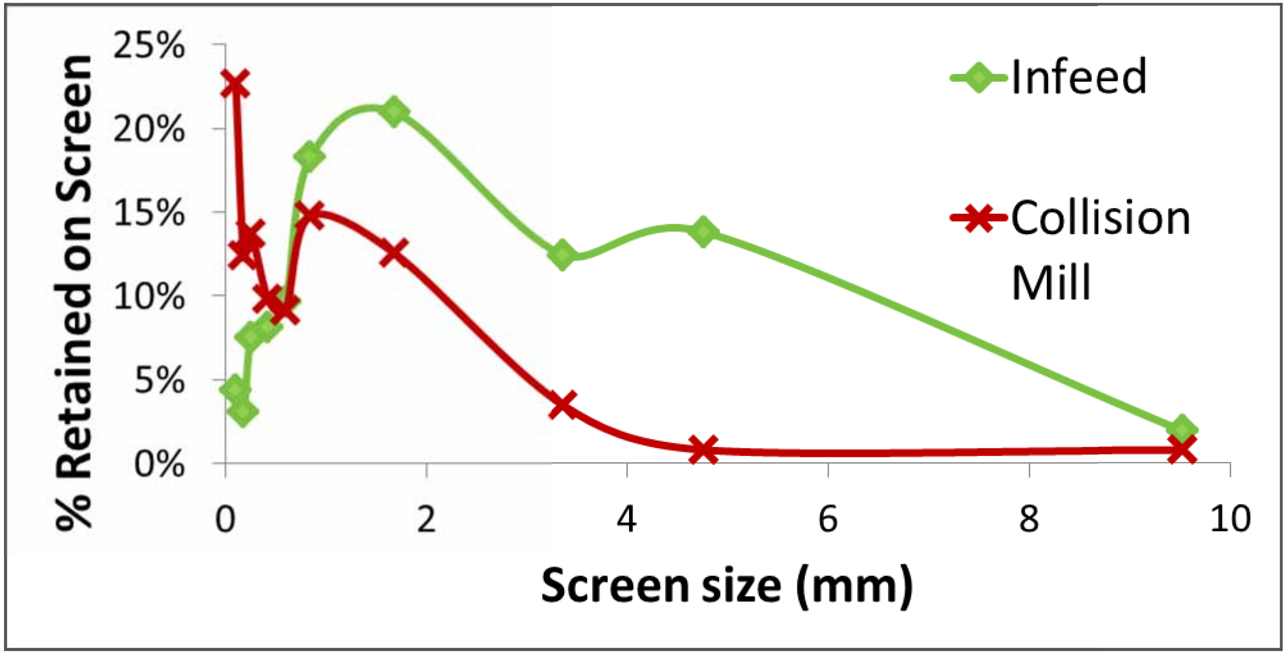
	BASELINE (FY 2013 Peer Review)	EXPANSION
Business Tools	CRADA, WFO	Non-proprietary user agreement
Users	DOE Projects	Industry
Markets	Biofuels	Biopower, waste-to-energy
Project Size	Small, 30 tons largest	Larger, 200 tons largest
PDU Utilization	~20%	Currently 80-90%

3 – Technical Results: Comminution Project

- Objective: Compare three comminution technologies for <u>secondary size reduction</u>
- Feedstocks: Corn stover, switchgrass, ponderosa pine each at three moisture levels
- Funding:
  - User Facility funds for testing, characterization, and reporting
  - Collaborator cost share (equipment readiness, travel, labor at INL)
- Collaborators: Forest Concepts, Vortex Processing

	Hammer Mill	Rotary Shear	Collision Mill
Capacity (tph)	5	1	1
Motor Size (hp)	150	20	30
Comminution Mechanism	Swinging hammers, 1-in. screen	24-in. wide row of interlocking 3/16-in. disks	Particle-particle collisions in air stream vortices

3 – Technical Results: Comminution Project



Infeed:

- Corn stover
- Bales processed through hammer mill with 6" screen

- Hammer Mill
  - Modest increase in "fines" compared to infeed material
  - Effective at grinding particles greater than 1.5 mm in size
- Rotary Shear
  - Did not create "fines"
  - Effective at grinding particles greater than 3 mm in size
- Collision Mill
  - Created the finest and "roundest" particles

3 – Technical Results: Comminution Project

Specific Energy Consumption

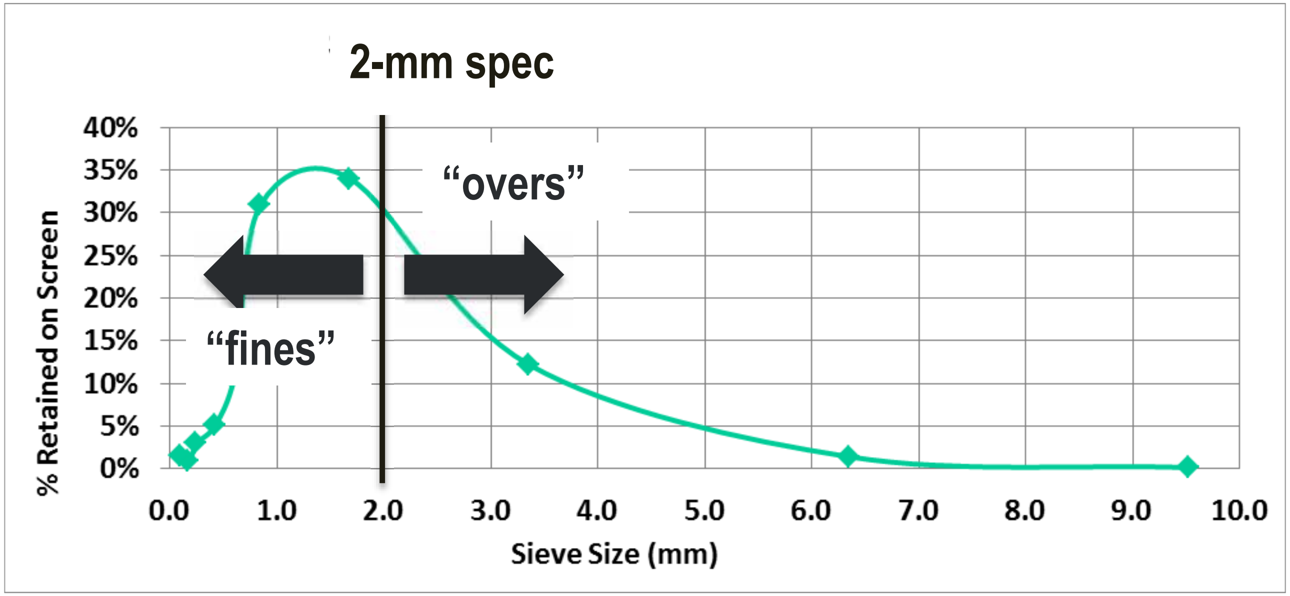
- Hammer mill and rotary shear
  - Comparable for switchgrass and low-moisture corn stover
  - Both required more energy with high-moisture materials
  - Rotary shear performed better with high-moisture corn stover
  - Hammer mill performed better with pine
- Collision mill
  - Energy requirements relatively high compared to the hammer mill and rotary shear
  - Energy use insensitive to moisture with switchgrass and pine; increased with corn stover moisture
  - Air currents inside the machine provide some drying capacity
- Corn stover is very “tough” when wet; 2 to 4.5 times more energy wet vs dry

Outcomes

- Collaborators: Independent 3rd-party data to improve, market, and commercialize their equipment
- INL & BETO:
  - Collection of data to inform State-of-Technology reports and TEAs
  - Identify further technology development needs

3 – Technical Results

The Least Understood Spec: Particle Size Distribution



How defined?

- Grinder screen size (19 mm)
- Sieve classification (2.1 mm mean)
- Optical measurement (2 < ps < 19 mm)

- "Overs" cause feeding and handling problems (e.g., bridging)
- "Fines" can cause conversion problems (premature combustion/pyrolysis)
- Particle size distribution (shape of curve above) affected by feedstock type, moisture, and screen size
- Processing parameters are selected to provide a balance between overs and fines

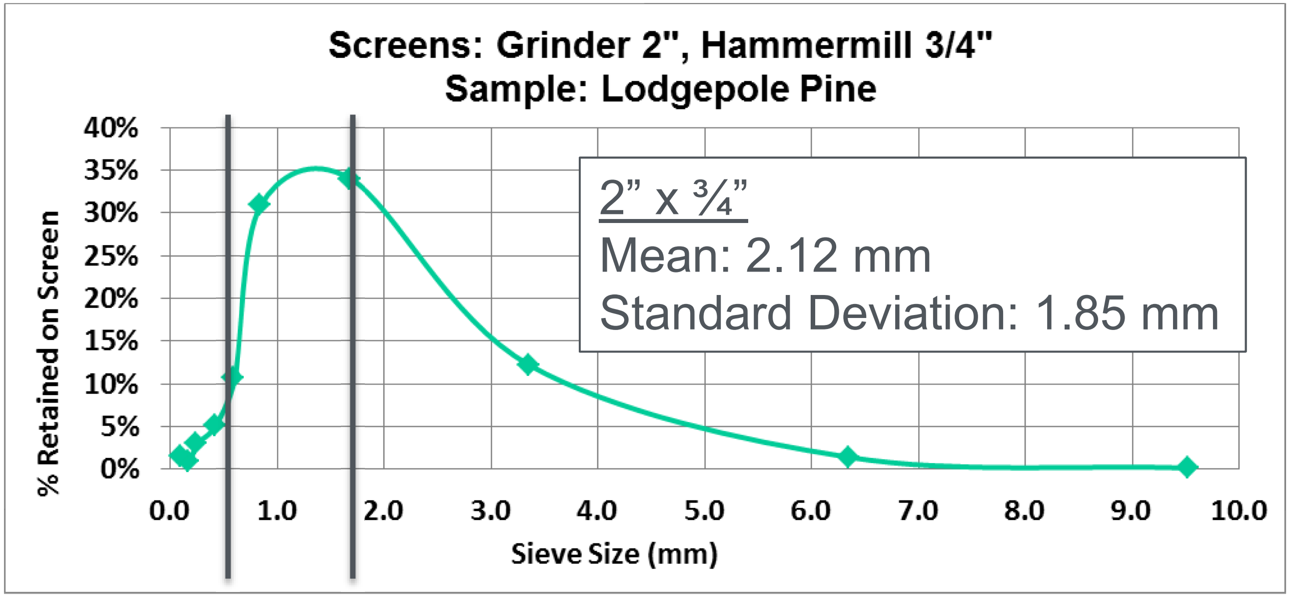
3 – Technical Results: Feedstock Supply

- Objective: Supply 40 tons of feedstock for a pyrolysis process validation
- Feedstock
  - Lodgepole pine (clean, debarked), corn stover (multipass), switchgrass
  - Specs included moisture, particle size max (overs) and min (fines), ash
- Funding:
  - User Facility funds for process development
  - DOE IBR funds for processing

Outcomes

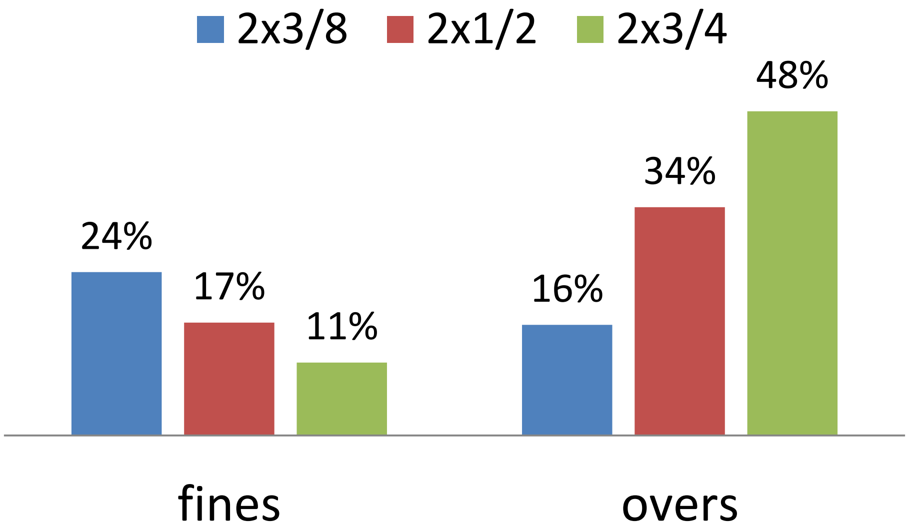
- Collaborators: Supported process validation with industrial feedstocks
  - Feedstock: sourced, processed, packaged, and shipped (~300 supersacks)
  - Feedstock characterization: moisture, particle size distribution, ash, and proximate/ultimate
- INL & BETO: Feedstock data (preprocessing, characterization) to support BETO pyrolysis pathway TEAs

3 – Technical Results: PDU Process Development



Challenge: Combined drying and grinding makes it difficult to achieve feedstock particle size specs.

- Fines end up as char
- Overs ("pin-chips") cause handling & feeding problems

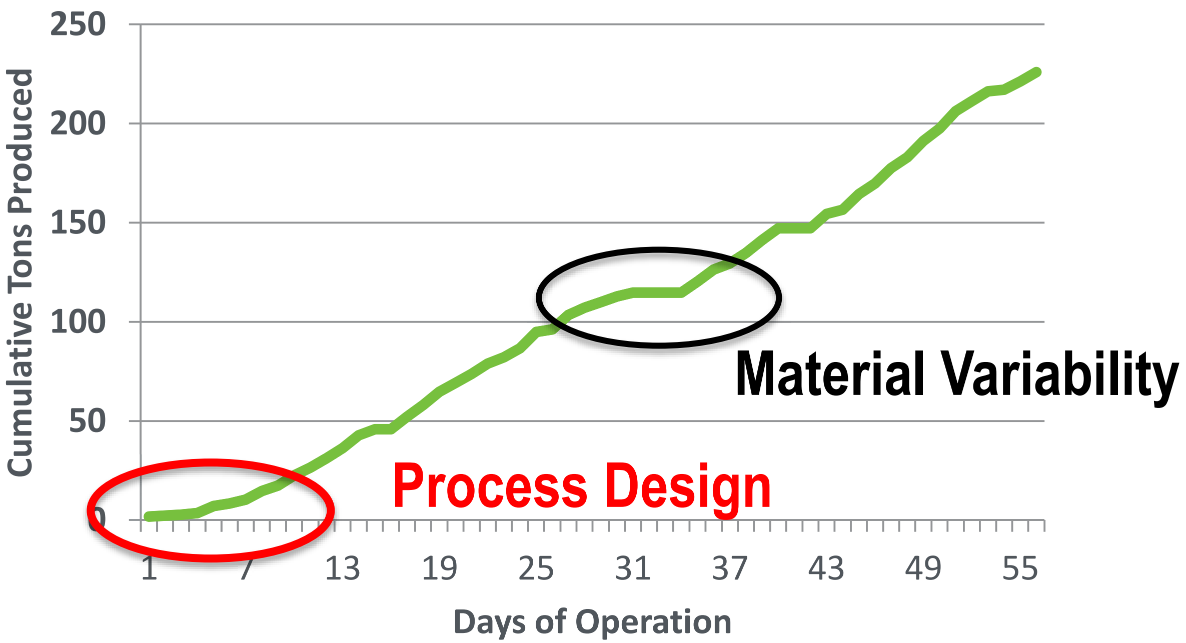


*Fines and overs not indicative of customer spec

3 – Technical Results: Co-Product Scale-Up and Integration

The Most Underrated Spec: Handling and Feeding

- Plants that process bulk solids operate at less than 50% of design capacity the first year of operation; this is often due to handling problems (from Rand Corp study)
- Handling problems arise from feedstock variability



Challenge:

- Scaling up a new process design, new equipment
- More integrated unit operations increases complexity
- Process designed without full understanding (data) of material variability

3 – Technical Results: Co-Product Scale-Up and Integration

- Objective: Scale-up and demonstration of co-product production
- Funding:
  - User Facility Funds for process development and PUD repair & maintenance
  - Partner funded WFO for processing, characterization, and shipping
- Industry partner:
  - Previously completed process R&D
  - Engaged User Facility for drying capability and reconfigurable design to accommodate a unique process flow and additional third-party equipment
- 200 tons of product, ~ 350 hours PDU operation: 3 months, up to 12 hours/day, 6 days/week

Outcomes

- Collaborators: Supported process validation with industrial feedstocks
  - Supplied 200 tons of product for combustion trial
  - Processing data and information to inform commercial design
  - Accelerated commercialization
- INL & BETO:
  - Machinery data and experience to quantify variability affects on preprocessing
  - Drying data to support Algae blending TEA

4 – Relevance

- User Facility projects highlight the importance of collaboration to not just provide a service, but solutions to feedstock challenges
- Collaborations are helping INL and BETO
  - Understand range of feedstock specifications
  - Understand what is driving these specifications
  - Understand the gap between specifications and what is achievable at an industrial scale
  - Identify innovative solutions to industrial preprocessing needs (closing the gap)
- Collaborations are helping our partners (users)
  - Understand the gap between specifications and what is achievable at an industrial scale
  - Understand what industrial feedstocks look like and perform like
  - Develop specifications that balance cost, performance, and reality
- User Facility projects are helping BETO
  - Supplying data to support BETO techno-economic assessments and state of technology reports
  - Provides input of industry feedstock needs

5 – Future Work

- Preprocessing Municipal Solid Waste
  - Evaluate feasibility of woody/herbaceous preprocessing designs to accept MSW as a slip stream
  - Collect data to support BETO techno-economic assessments of MSW as a blendstock
  - Compare densification options (pellet, cube, and briquette) based on energy input, feedstock quality (density and durability), and conversion performance
  - Supply feedstocks to collaborators for testing
  - Involves 2 waste-to-energy collaborators: InnerPoint Energy, Cogent Energy Systems
- Biopower Feedstock Specs
  - Develop feedstock densification specifications for handling, feeding, and combustion
  - Collect data to support BETO feedstock techno-economic assessments
  - Supply feedstocks for test burn(s)
  - Involves three collaborators: Repreve Renewables, Univ. of Iowa, and PHG Energy

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5 – Future Work

- Control system development of integrated preprocessing system
  - Integrate grinding, drying, and pelleting process models
  - Dynamically control system to control processing variables to optimize energy consumption, throughput, and/or product quality
- Expand user facility capabilities
  - Mobile torrefaction system, 2 to 3-ton/hour throughput
  - Cubing system module for PDU, 3 to 5-ton/hour throughput
  - Improve modularity to simplify adding third-party equipment modules to PDU
- Go/No-Go Milestone to evaluate current project selection and review process for impact to BETO programmatic goals and objectives
- Business tools – working internally to
  - Reduce project development time
  - Streamline contracting reviews and approvals
  - Automate the PDU project report

Summary

- Approach
  - Active industry engagement and project development to ensure relevance to BOTH industry and DOE-BETO
  - Data collection to understand industry needs and the life cycle of the project's offering/capabilities
- Technical Accomplishments
  - Interaction with conversion technology developers is useful in identifying the range of feedstock specifications for different processes
  - Knowledge base of process design for feedstock preprocessing and equipment performance capabilities and needs will accelerate scale-up and integration of biomass preprocessing
- User facility provides a unique and critical capability for projects
  - Requiring an integrated system
  - That are too large
  - That are too complex for industry test laboratories

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