INL/MIS-21-61544-Revision-0

Biomass Feedstock National User Facility--Improving Bale Deconstruction and Material Flow

March 2021

Changing the World's Energy Future

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Idaho National Laboratory

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DOE Bioenergy Technologies Office (BETO) 2021 Project Peer Review

WBS 3.4.1.202 Biomass Feedstock National User Facility – Improving Bale Deconstruction and Material Flow

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Date
Technology Area Session

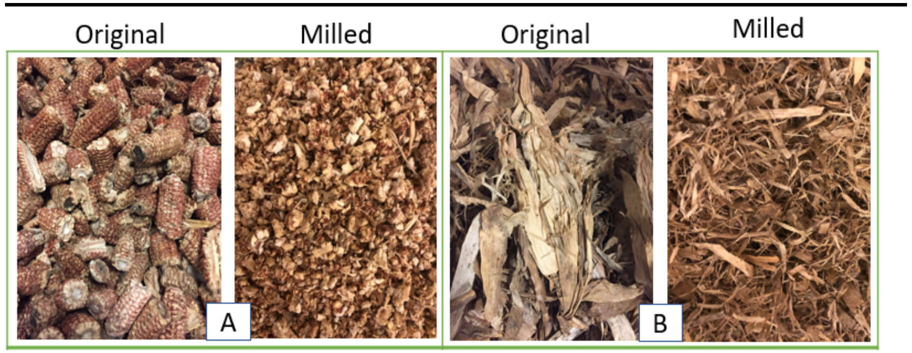
Neal Yancey
INL

Project Overview

- **Objective:** Reduce the variability in feedstocks using a Quality by Design (QBD) approach beginning at the introduction of the biomass and continuing through the size reduction process. This will result in:
  - Reduction of fines generation and removal of contaminants (tramp metal, rock, soil, etc)
  - Controlling physical and chemical critical material attributes throughout the process
  - Managing flowability and achieving nameplate capacity and efficiency

This will be accomplished by:

- Eliminating high speed bale deconstruction for more uniform flow and particle size control
- Replacing, when necessary, high speed impact size reduction mills with lower speed shear milling for 3-dimensional particle size control and fines reduction
- Screening to achieve desired particle size and shape, and reduce over processing
- Sorting to separate anatomical fraction, different density particles, and contaminant removal, etc.



Project Overview (con’t)

- **Current Limitations:** Inherent physical and chemical variability in feedstocks inhibit their raw use in bioenergy processes leading to high inefficiencies, excessive process downtime, and uncontrolled costs with documented failures in the industry as a whole. Common high-speed milling operations do not address core problems of excessive fines, contaminants, and particle size and shape differences or poor flowability
- **Relevance:** Manage variability in preprocessing operations through:
  - Experimentally-derived interactions in material feeding
  - Machine learning and automation to minimize human error
  - TEA/LCA Implications:
    - Value proposition of ash removal on downstream equipment wear
    - Value proposition of material attributes on deconstruction reactor design/operation
- **Risks:**
  - Multi-dimensional, multi-scale problem
  - Timely adaptation of preprocessing equipment for maximum impact
  - Effective dissemination of tools and knowledge for maximum market impact

1 – Management

This project is managed by Neal Yancey. It is divided into 3 main task and 8 subtasks presented in the table below:

Subtask	Lead(s)	Major Responsibilities
Task 1 - Advanced Preprocessing Research and Development and Scale Up		
Task 1A	Neal Yancey	Material Introduction
Task 1B	Jordan Klinger	FY2022 Verification
Task 1C	Luke Williams	Hydrodynamic Separation
Task 2 - Machine Learning, System Automation, Sensor Development and Datta Management		
Task 2A	Patrick Bonebright	Machine Learning and Automation.
Task 2B	William Smith	Sensor Development
Task 2C	Robert Kinoshita	Data Management
Task 3 - BFNUF Requests and Feedstock Supply		
Task 3A	Luke Williams	User Facility Requests
Task 3B	Neal Yancey	Feedstock Supply

Risks: Lack of communication between industry and laboratories; Lack of synergy between experimentation and modelers; lack of synergy between researchers at various laboratories

1 – Management (continued)

- **Communication strategy –Cross-task collaborations:**
  - Pis, Task Leads, LRM and BETO TMs monthly meetings
  - Monthly subtask meetings
  - Quarterly cross task collaborations
  - Joint milestones with other Tasks
  - Coordination with Task members on other tasks
    - Dave Thompson and Damon Hartley - Modeling
    - Vicki Thompson - FCIC
    - Rachel Emerson and Amber Hoover Characterization
    - Jordan Klinger – Material deconstruction
    - Bill Smith – Sensor development
    - Robert Kinoshita – Data Management
  - Participation with lab-industry partnerships (DFO projects)

Risks: Lack of communication between industry and laboratories; Lack of synergy between experimentation and modelers; lack of synergy between researchers at different laboratories

2 – Approach

Technical Approach:

- Develop new hypothesis for overcoming inherent feedstock variability based on previous experimental testing
- Develop methods based on experimental data to achieve and predict 3 dimensional milling approaches, feedstock sorting, and advanced fractionation.
- Determine process parameters to achieve quality attributes defined by the 2022 verification effort
- Generate process data (i.e. throughput, energy requirements, etc.) to inform TEAs/LCAs and the 2022 verification

Challenges:

- Maintain connection with other national labs regarding process parameters for the most critical attributes
- Transition novel concepts into industrially relevant technology
- Coordinate experimental testing and results between tasks

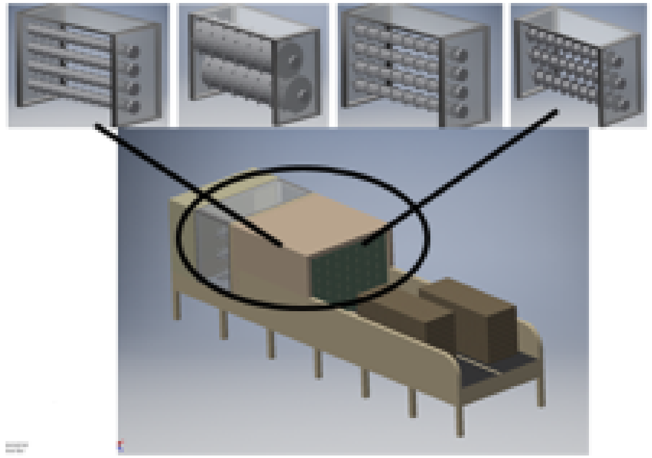
Metrics:

- Demonstrate scale up of industrial relevant approaches that support TEAs/LCAs and the 2022 Verification
- FY21 Go/No Go –Complete the integration of fractional milling for pine and pine residue
  - Reduce standard deviation for amperage by 25% and increase throughput for woody biomass by 30%. Reduce the non white wood fraction (bark, needles, etc.) by 75% in the clean fraction.
- Demonstrate a systematic approach including product infeed, milling, sorting, and fractionation to multiple finished product lines. This will support SOT development and FCIC Task 8
- Demonstrate a 25% reduction in attrition (fines) combined with a 30% decrease in Ash in corn stover and pine

3 – Impact

Impact:

- Custom designed Low speed bale processors will support downstream separation and size reduction technologies designed to meet key material attributes
- Size reduction to achieve 3-dimensional control of particle size will improve flowability and conversion efficiency
- Separation to meet feedstock quality attributes resulting in increased operational and conversion efficiency and reliability
- Subsequent conversion unit operations will benefit from predictable material attributes and controllable process parameters that result in improved conversion performance and reliability



A custom debaler can deconstruct biomass and municipal solid waste bales for **more reliable downstream separations and size reduction.**

Dissemination:

<u>Near term</u>:

- Peer-reviewed journals <u>and</u> trade journals
- Virtual and Real Industry Workshops
- Collaboration with industry partners
- Conference presentations

<u>Long term</u>:

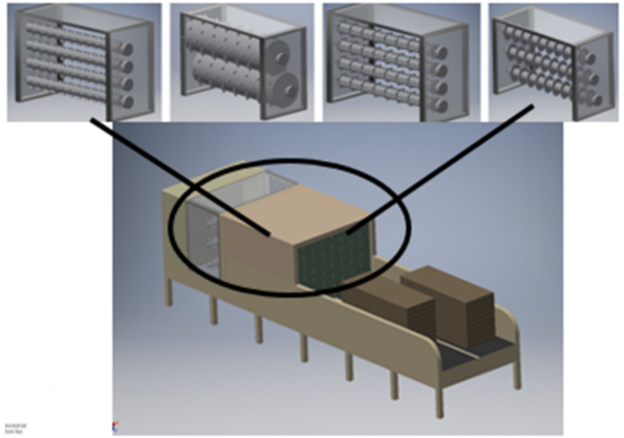
- Demonstrate applicability to industrial stakeholders
- Design control capabilities to mitigate feedstock variability
- Team with industry to bring technology to market

4 – Progress and Outcomes

Improved Material Introduction

Low Speed Specifically Designed Material Introduction:

- **Lower attrition rates**
- **Support down stream anatomical fractionation**
- **Consistent particle sized and distribution**
- **Lower energy requirements**
- **Consistent feeding and conveyance**



	Mean (mm)	**% less than 1 mm**	**% less than 6 mm**
Vermeer 6 inch	6.01	5%	47%
Vermeer 3 inch	5.97	12%	62%
Bale Processor	15.9	2%	15%

Description

High speed bale deconstruction results in excessive generation of fines, uneven flow and increase energy costs.

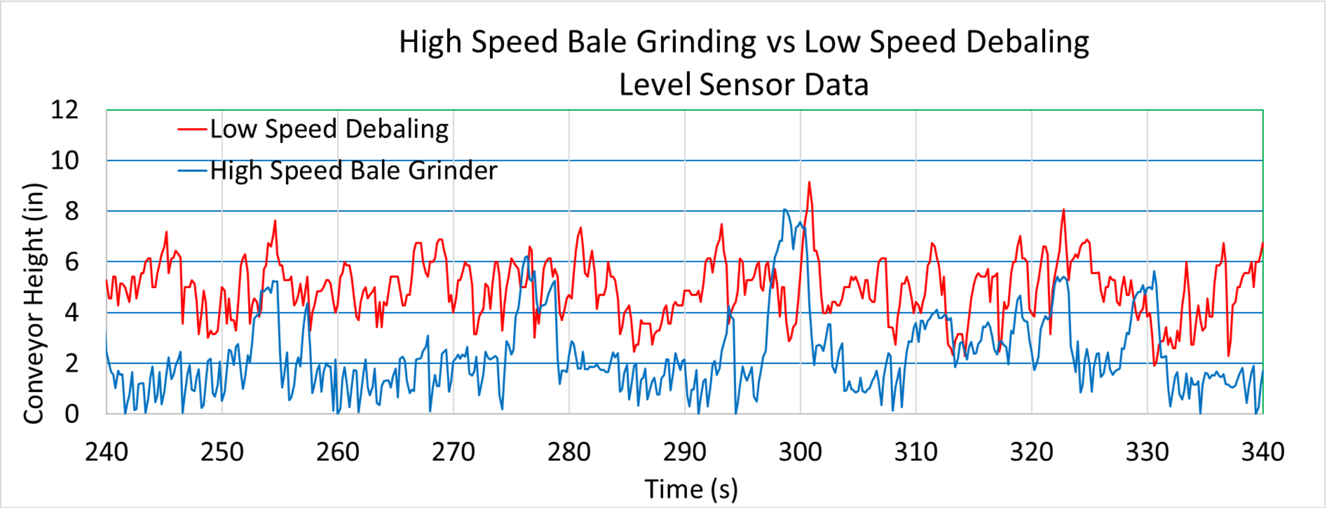
Value of new tool

Fewer material losses as fines, better performance in downstream conversion, improves contaminant removal and enables anatomical or waste type fractionation.

Potential Customers & Outreach Plan

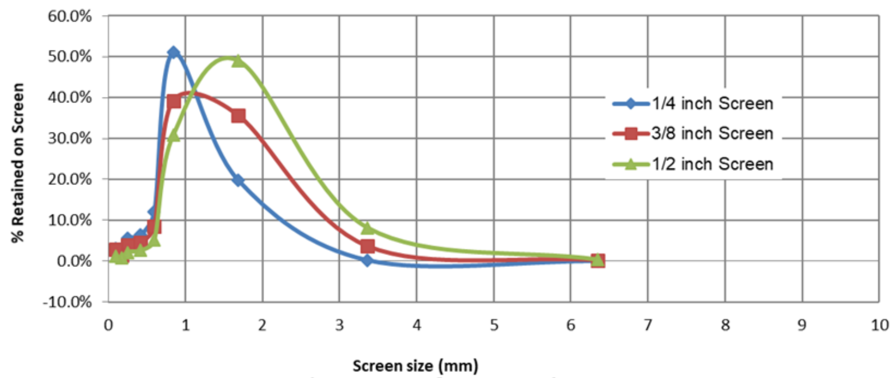
Biorefineries, mill operators and mill designers

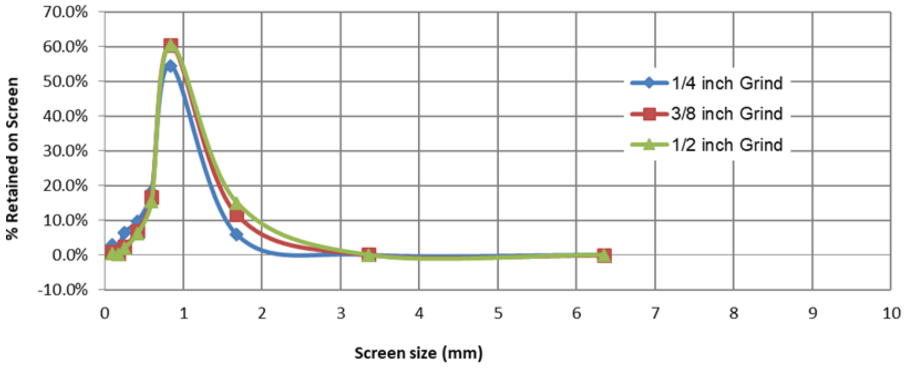
Publication, trade shows and public release of code



Screening Implementation

Appropriate screening timed specifically in the process will result in:
- **Lower attrition rates**
- **Support down stream anatomical fractionation**
- **Consistent particle sized and distribution**
- **Lower energy requirements**
- **Consistent feeding and conveyance**





Description

Screening Advances the Fractional Milling approach by reducing energy, improving particle sizes distributions, and removing contaminants.

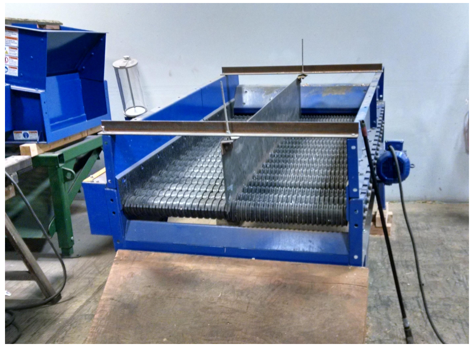
Value of new tool

The new screen have enable early removal of contaminants, reduce energy consumption and wear, supports anatomical or tissue fractionation, and result in consistent particle size distribution

Potential Customers & Outreach Plan

Biorefineries, mill operators and mill designers

Publication, trade shows and public release of code



Disc Screening:
- Contaminant removal
- Minimize attrition
- Supports anatomical fractionation

Orbital Screening:
- 3-dimensional particle
- Supports fractional milling
- Achieve CMAs

Air Classification

Air Classification is used at the BFNUF to:

- **Achieve anatomical fractionation**
- **Improve contaminate removal**
- **Separate materials of different densities**

<u>Large Scale Air Separation</u>:

- Separates stalks, cobs, leave and husks
- Separates bark, needles, and whitewood

<u>Small Scale Air Separation</u>:

- Tissue separation
- Separates bark, needles, and whitewood
- MSW fractionation

Description

At the BFNUF air classification is used to separate anatomical fractions as well as to separate tissue fractions or MSW types in milled materials.

Value of new tool

Separation of the anatomical fractions allows the BFNUF to look at milling approaches tailored to those fractions to achieve specific CMAs for that material.

Potential Customers & Outreach Plan

Biorefineries, mill operators and mill designers

Publication, trade shows and public release of code

	Clean Chips	Bark	Bark and Wood Connected	Needles	Unclassified Particles
Prior to Air Separation	73%	7.0%	3.5%	0.8%	15.2%
After Separation High Moisture	85%	4.0%	0.58%	0.12%	10.28%
After Separation Low Moisture	94.2%	2.1%	0.6%	0.1%	3.0%
% Change High Moisture	+15.7%	-42.5%	-83.4%	-85.5%	-32.4%
% Change Low Moisture	+28.2%	-69.5%	-83.7%	-93.7%	-80%

Density Separation

Separation based on density using a Specific Gravity table:

- **Separate fractions based on tissue type**
- **Separate MSW based on material or plastic type**
- **Requires uniform particle size.**

Description

The BFNUF uses the Oliver Specific Gravity table to separate tissue fractions in both woody and herbaceous material once it has been milled. MSW can also be fractionated into different densities of plastics, paper, fabric or contaminant removal

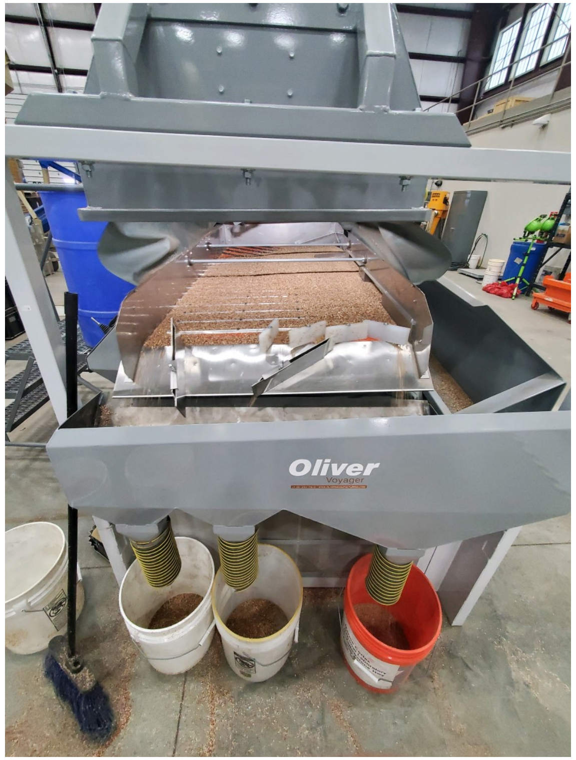
Value of new tool

Separation of the tissue fractions allows the BFNUF to control material attributes, particularly chemical attributes, at a much higher level than standard practices.

Potential Customers & Outreach Plan

Biorefineries, mill operators and mill designers

Publication, trade shows and public release of code



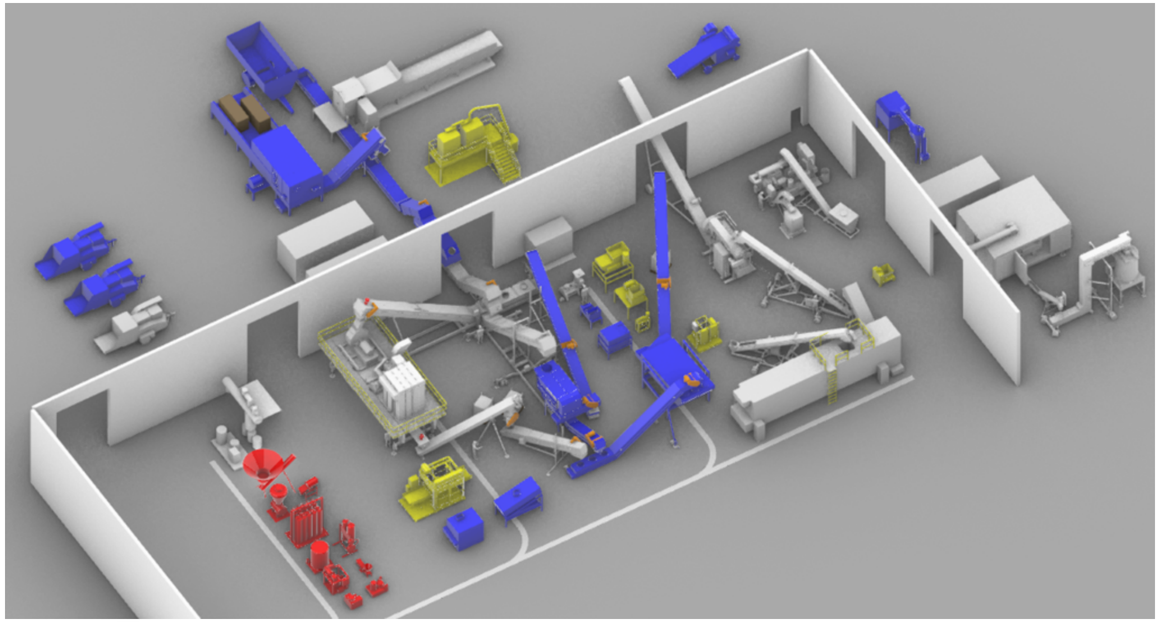
<u>Specific Gravity Separation</u> :

- MSW fractionation – separating fluff from discrete plastic particles above
- Tissue separation pith from rind of corn cobs on the left

High - 223 kg/m3 Medium – 67 kg/m3 Light 45 kg/m3

BFNUF an Industry Scale-up Test Bed

The BFNUF is a system of multiple preprocessing capabilities that can be used on a variety of feedstocks and industries to:
- **Improve material flow**
- **Increase feedstock value**
- **Remove inherent variability in highly variable feedstocks**



Description

The BFNUF incorporates a variety of preprocessing applications including:

- Material introduction – chippers, shredders, bale processors,
- Screening – disc, oscillating, shaking, PDU scale to bench scale screens
- Sorters – robotic, mechanical, air, density

With a central aim of

- Reducing energy costs
- Meeting physical and chemical material attribute
- Defining define process parameters for each unit operation

Value of new tool

Developing the biofuel industry by creating consistent feedstocks for a variety of conversion pathways.

Potential Customers & Outreach Plan

Biorefineries, mill operators and mill designers

Publication, trade shows and public release of code

Summary

FY21 Q1 milestones required that the BFNUF meet the following goals using fractional milling of forest residue

- *Achieve a 25% reduction in standard deviation of the amperage at the stage 2 grinder*
  - *We achieved a 55% reduction in the standard deviation and reduced the energy consumption by 25%*
- *Achieve a 75% reduction in non-whitewood fraction of residue using air classification and screening*
  - *We increased the whitewood chip fraction from 73% in the raw feedstock to 94% whitewood following air classification. The bark fraction went from 7% in the infeed to 2.1% after air classification. The needles went from 0.8% to 0.1% following air classification. In addition we reduced the total ash from 2.62% in the raw forest residue to 1.02% following air classification, milling, and screening to remove fines.*

This was achieve using the 2020 upgrade to the BFNUF which included

- *Consistent feeding using the PDU scale mixer/feeder*
- *Air classification using the Spudnik Air separator*
- *West Salem oscillating screen*

Summary

The FY21 Q1 research also included supporting efforts to meet the 2022 Verification project. This research is focused on meeting Critical material attributes for forest residue. This was achieved through

- *Air classification*
- *Forest Concepts Crumbler*
- *Oscillating screens*
- *Oliver Specific Gravity table*

WBS # 3.4.1.202

Timeline

- 10/01/2018 - 09/30/2021

	FY20	Active Project
DOE Funding	$1,713K	FY19- FY20- $2,306 <u>FY21- $1,713</u> Total- $4,019

Project Partners (N/A)

Barriers addressed

Ct-A - Reducing variability through screening/sorting
Ct-C Improving preprocessing efficiency
Ct-J - Developing process integration to achieve material attributes
Ft-I - Integration and scale up

Project Goal

Develop science-based design and operational principles that improve feeding, handling, and control critical material attributes that have historically resulted in failure by the industry. Utilize a quality-by-design approach to create, quantify, and capture feedstock fractions with narrow physical and chemical quality distributions to support low and high temperature conversion processes.

End of Project Milestone

Completion of the Advanced Fractionation System Approach (including bale deconstruction, screening, air classification, and mechanical separation/sorting) and demonstration of Fractional Milling approach, resulting in a 25% reduction in fines generation, 50% increased system throughput, maintain an average milling amperage at 75% of full load amps, and 50% reduction in the standard deviation around the mean particle size.

Funding Mechanism (N/A)

*Only fill out if applicable.

Additional Slides

Material Introduction

- **Low speed bale deconstruction reduces the generation of fines**
- **The new bale processor can be configured for a variety of feedstocks – corn stover, MSW, etc.**
- **This enables contaminant remover prior to size reduction**
- **After debaling, feedstocks can be easily sorted using screens, air classifiers, or robotic separators as needed**

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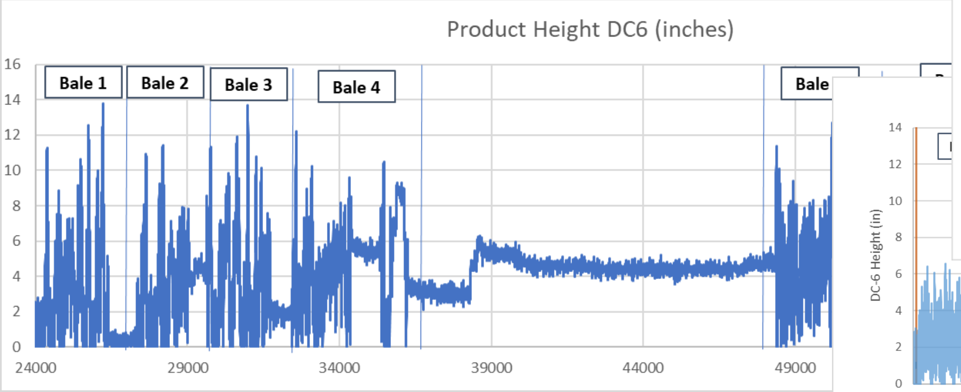

Description

The Warren and Bearge bale processeor uses low speed debaling drums with fingers rather than knives or hammers to decompress and untangle the corn stover and create a uniform flow of biomass

Value of new tool

This tool allows for easy separation of rocks or tramp metal following the bale processor decreasing downstream equipment wear and reduces the generation of fines caused by high speed bale grinders

Potential Customers & Outreach Plan

Biorefineries, mill operators and mill designers

Publication, trade shows