WASTE TO WISDOM

Production of Quality Feedstock From Forest Residues for Emerging Biomass Conversion Technologies

U.S. DEPARTMENT OF ENERGY

HUMBOLDT STATE UNIVERSITY

For more information please visit WasteToWisdom.com

Introduction to Waste to Wisdom

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Forest residues

Forest residues

Forest Residues

Forest residues

- ✓ **Materials difficult to handle:**
  - Mix of various species/size/shape
  - Low bulk density
- ✓ **Pre-processing in the woods needed for efficient handling and utilization**

In-woods biomass handling methods

Grinding

Chipping

Typical in-woods biomass operation

Grinding

Chipping

Transportation

High cost

Energy plant

Low market price paid

Challenges in biomass harvesting…

"Low traveling speeds on forest roads"

Felling/Bunching
$6.37/BDT (11.5%)

Skidding
$6.08/BDT (11.0%)

Loading
$4.08/BDT (7.4%)

Grinding
$12.63/BDT (22.9%)

Total Cost = $55.27/BDT
(Stump-to-Plant)

Hauling
$26.11/BDT (47.2%)

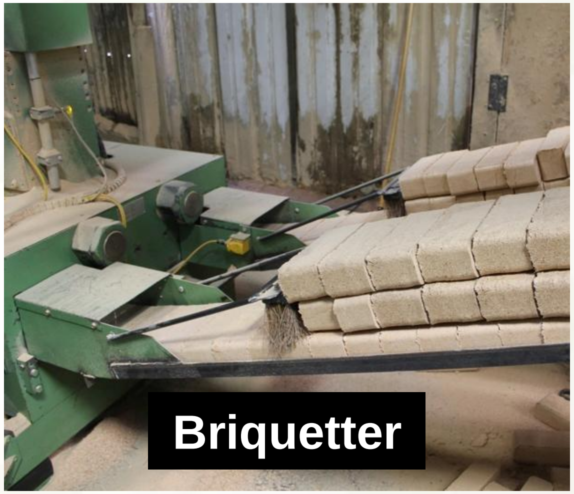
(30 – 36 miles one-way)

Integration of biomass conversion technologies (BCTs) with in-woods biomass operations


In-woods Biomass Operations


Torrefaction


Gasification


Briquetter

In-woods biomass conversion

- ✓ Decrease transportation and handling costs
- ✓ Increase product values

Waste to Wisdom – Project goal

Production of bioenergy and bio-based products through effective utilization of forest residues by development of new biomass conversion technologies and optimized biomass operations logistics.

Waste to Wisdom – project organization

- **Feedstock Development**
  - ✓ Forest residue sorting, arranging, baling, chipping/grinding, and screening to produce quality feedstock

- **Biomass Conversion Technology Development**
  - ✓ Gasification, torrefaction, and briquetter

- **Bioenergy and Biobased Products Development Analysis**
  - ✓ Determining economic and environmental success of utilizing forest residues for production of bioenergy, and biobased products

Forest residues: sorting and arranging for production of quality feedstock

Presented by:

Anil Raj Kizha., PhD.

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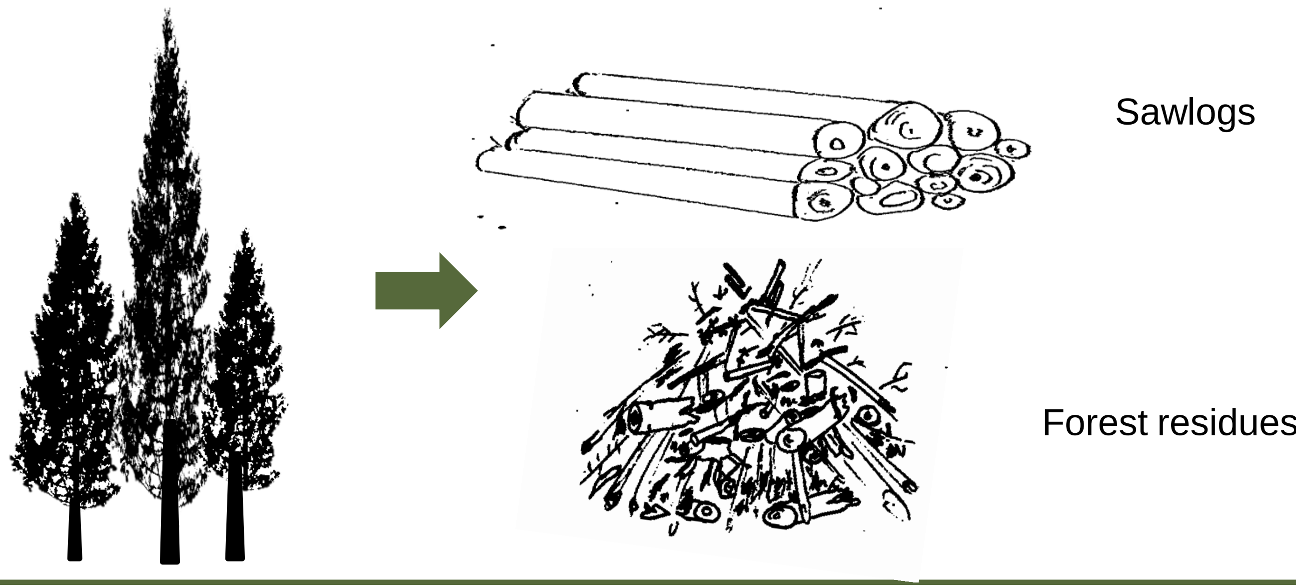
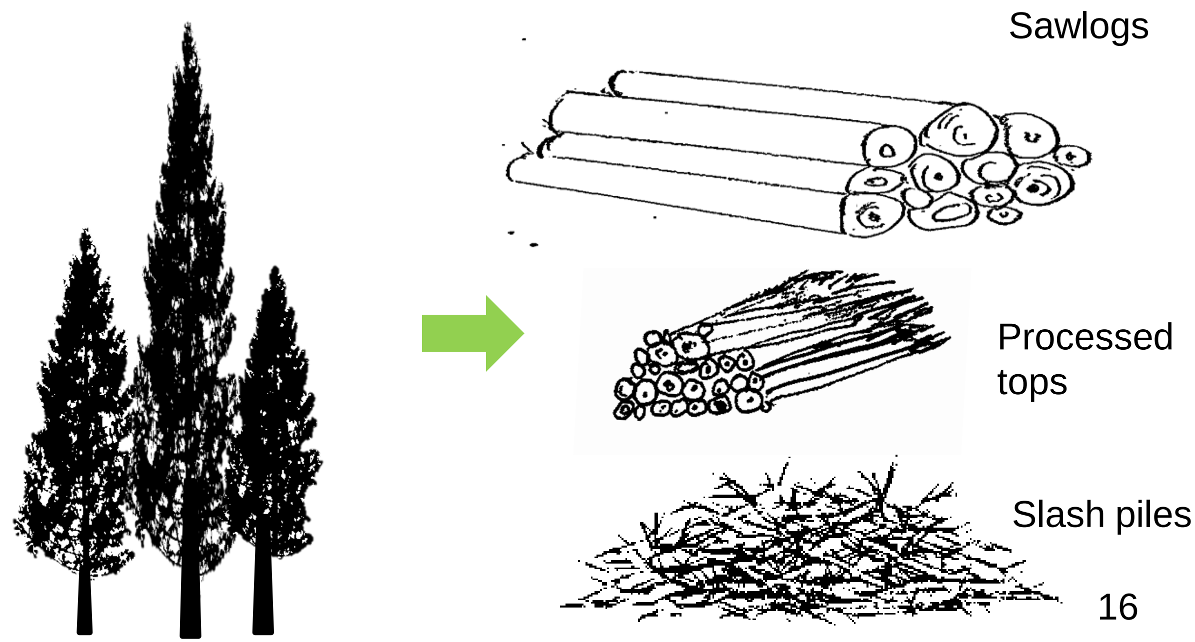
Sorting and arrangement of forest residues

- BCT(torrefaction, biochar, and gasification) can enhance the economic potential of these residues
- Require higher quality feedstock: uniform in size, moisture content, and contamination
- Difficult to produce quality feedstock from forest residues containing mixed materials



No sorting (current practice)

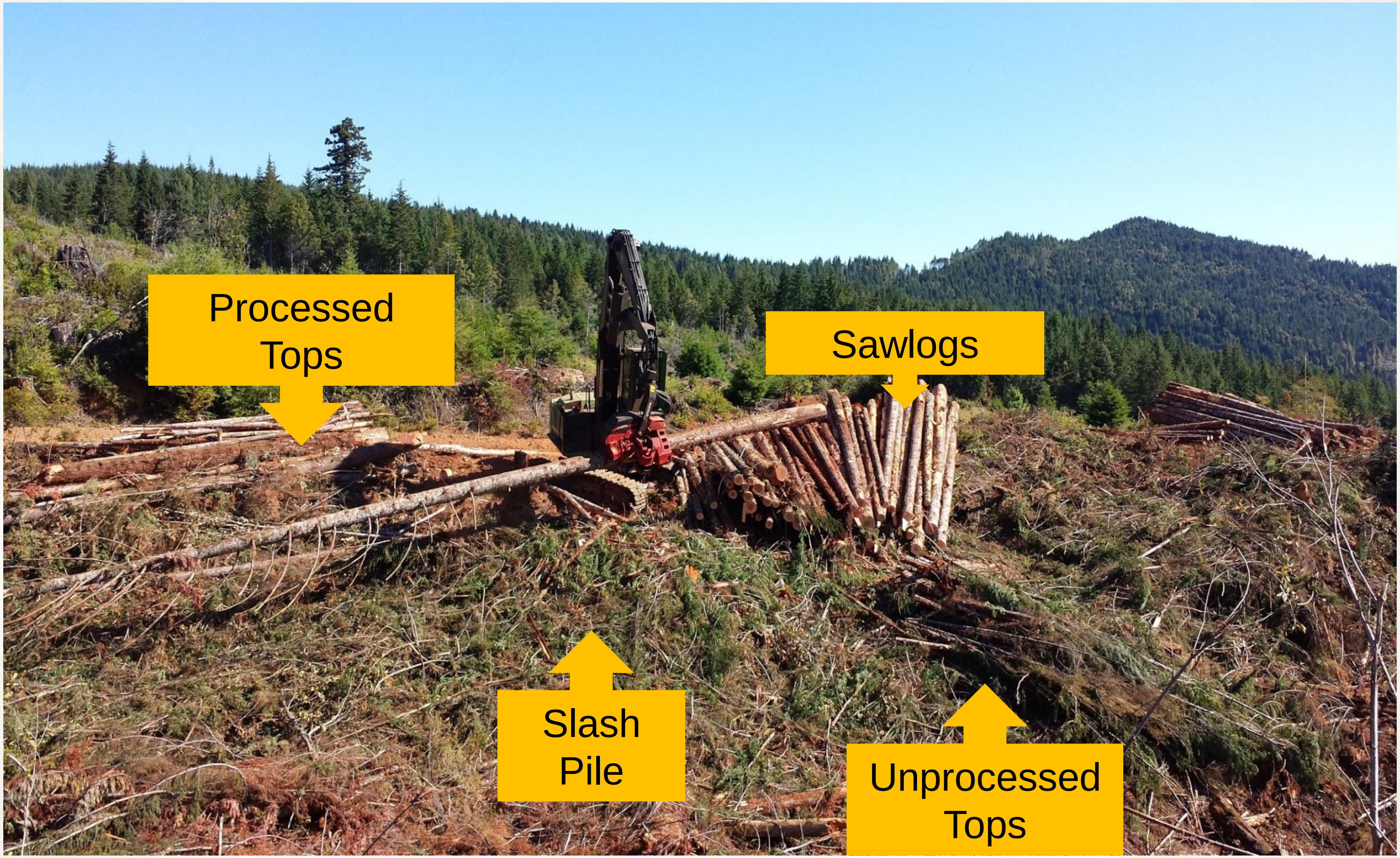
Sorting tree tops



Aim

- Estimate the cost differences associated with the varying degrees of processing and sorting forest residues
- Identify major factors that affect the overall cost and productivity
- Estimate the moisture content reduction in forest residues through different arrangement patterns

Sorting and processing tops




1


2


3


4
STIHL

How and what we did ...

Productivity

- Stand inventory
- Time and motion study
- Log deck scaling
- Scale tickets
- Machine rate calculation

Influential factors

- Standardized comparison
- Component analysis

Moisture Content

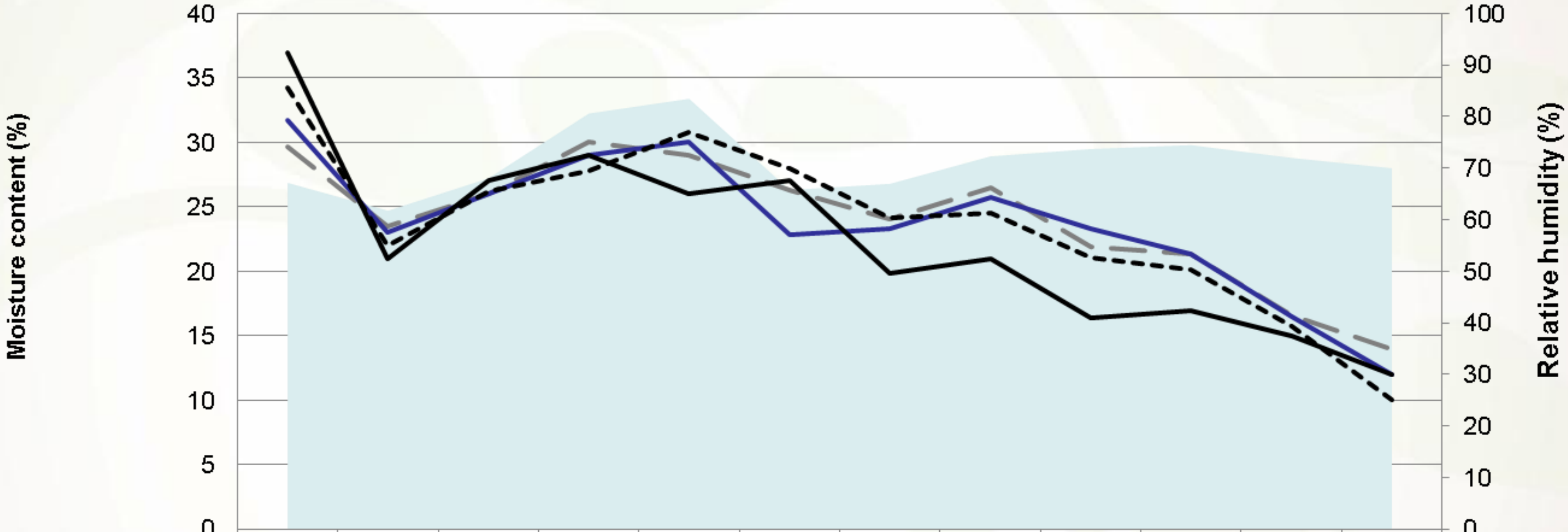
- Transect Sampling
- Disc collected
- Oven drying
- Weather data

Cost of operation

Sawlog ($/MBF)

	Sorting		
	No sorting	Moderate	Intensive
Feller Buncher	$ 13.28	$ 12.46	$ 15.43
Shovel	$ 45.68	$ 47.43	$ 46.30
Processor	**$ 18.98**	**$ 21.97**	**$ 26.04**
Loader (loading)	$ 12.64	$ 12.31	$ 12.40
Loader (sorting)	$ 6.18	$ 6.08	$ 6.02
Total	**$ 96.76**	**$ 100.24**	**$ 106.19**

Moisture content reduction



	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July
Relative humidity (%)	67	62	68	81	83	66	67	72	74	74	72	70
Teepee	30	23	26	30	29	26	24	26	22	21	17	14
Criss cross	32	23	26	29	30	23	23	26	23	21	17	12
Processor pile	34	22	26	28	31	28	24	24	21	20	16	10
Scattered	37	21	27	29	26	27	20	21	16	17	15	12

Managerial Impacts

- Increase in cost due to sorting and processing of forest residues : $ 465/ acre
- Saving in site preparation cost: $ 300 - 800 / acre

Additional revenue

- Production of higher quality comminuted feedstock
- Market for “tree-top” logs as dowel, post-pole, etc.

Thank you

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Evaluating the quality of feedstock produced from sorted forest residues

Presented by:

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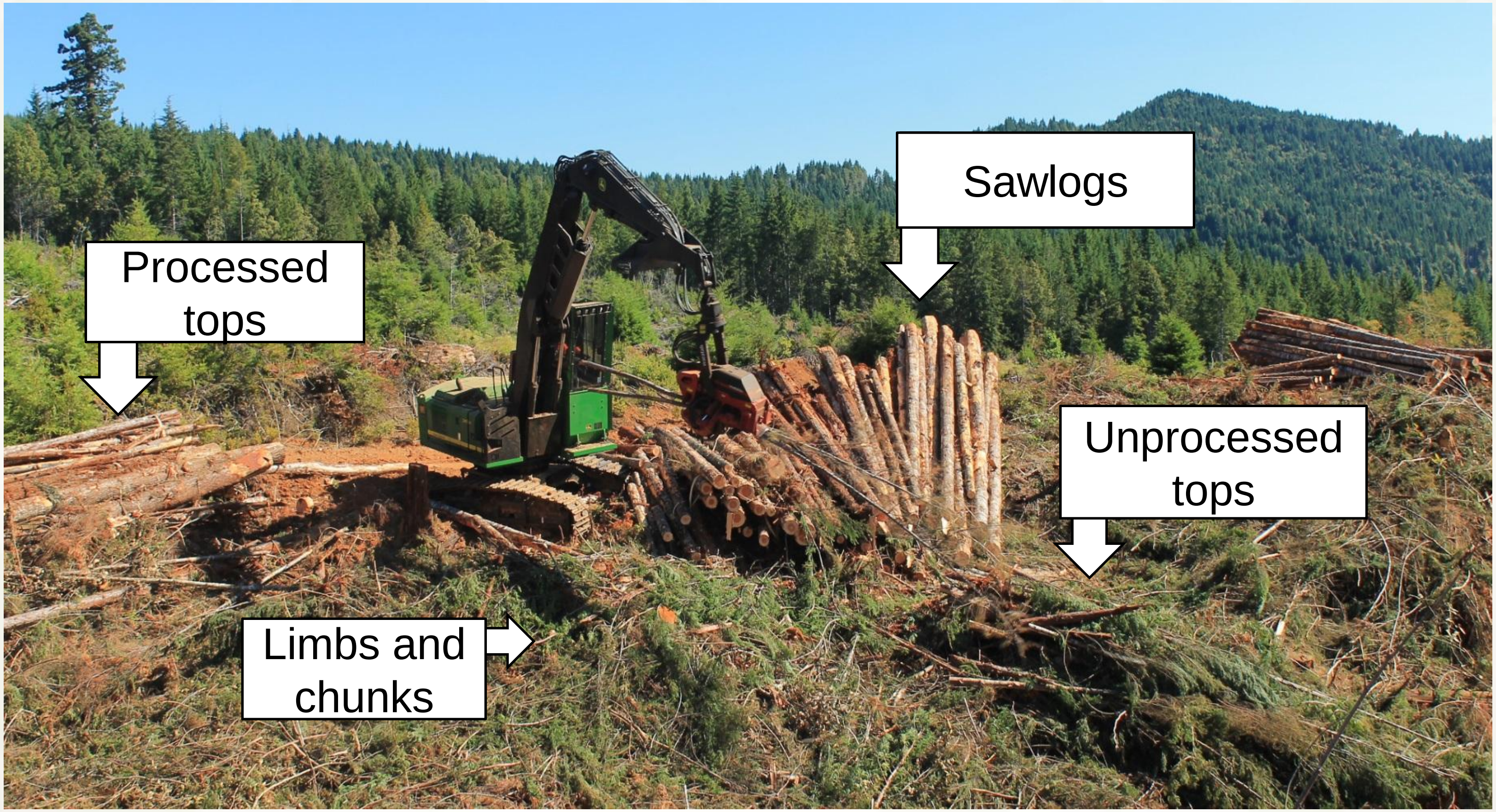
Why quantify feedstock quality?

1. Compare feedstock generated from grinding slash with chips generated from sorted residues



Why quantify feedstock quality?

2. Provide BCT research team with specific characteristics that are possible from forest residues.

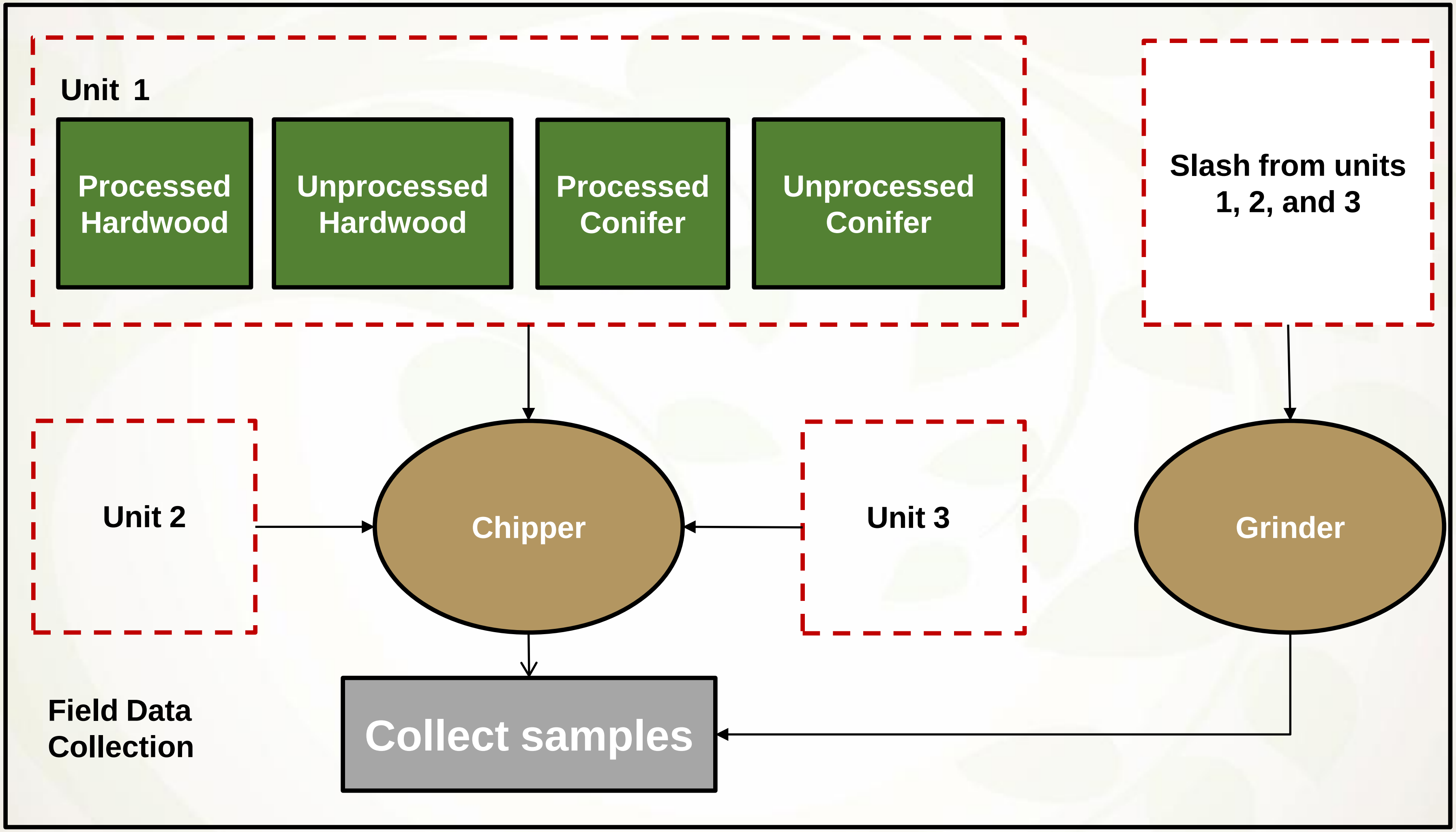
- Particle size
- Moisture content
- Ash content
- Bulk density

Why quantify feedstock quality?

Biomass Conversion Technology	Particle size (inch)	Moisture Content (% wet basis)	Ash content (%)
	Current desired feedstock specifications		
Torrefaction	< 1.5	< 30	?
Densification	< 2	< 15	NA
Pyrolysis	< 4	< 25	< 20%

Material generated from sorting and processing residues

Experimental design



Characterizing different material types

Material type		Bark cover (%)	Average volume (cubic feet/piece)
Processed conifer	PC	68	5.1
Unprocessed conifer	UC	92	2.9
Processed hardwood	PH	71	5.3
Unprocessed hardwood	UH	95	2.5

- 24% reduction in bark cover as a result of processing
- Processed material was greater in volume

Field data collection

Chipping processed and unprocessed, conifer and hardwood stems and tops

- A total of 156 samples were collected
- Three day operation

Field data collection

Grinding slash material

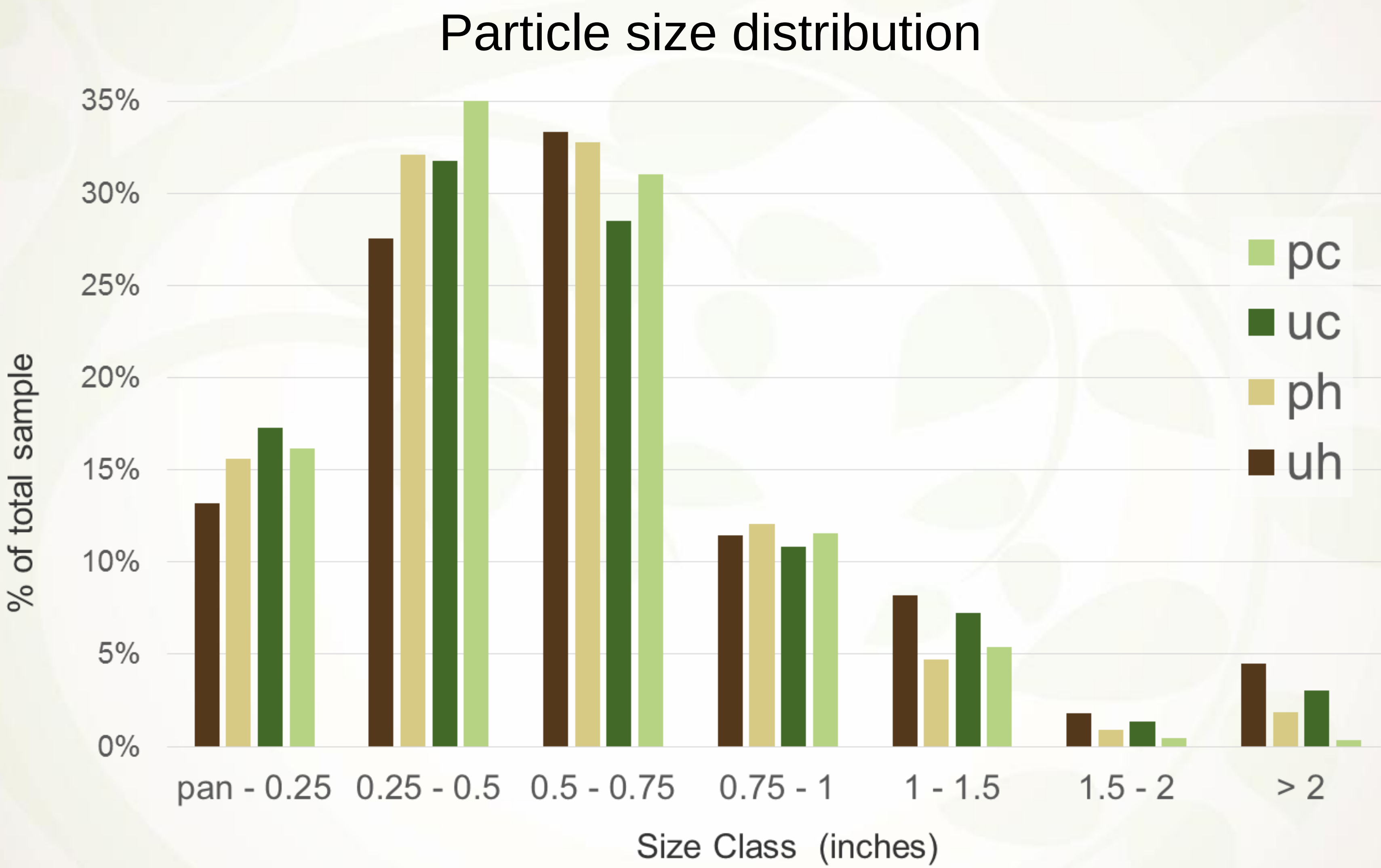
Laboratory analysis

- Particle size distribution
- Moisture content
- Bulk density
- Ash content

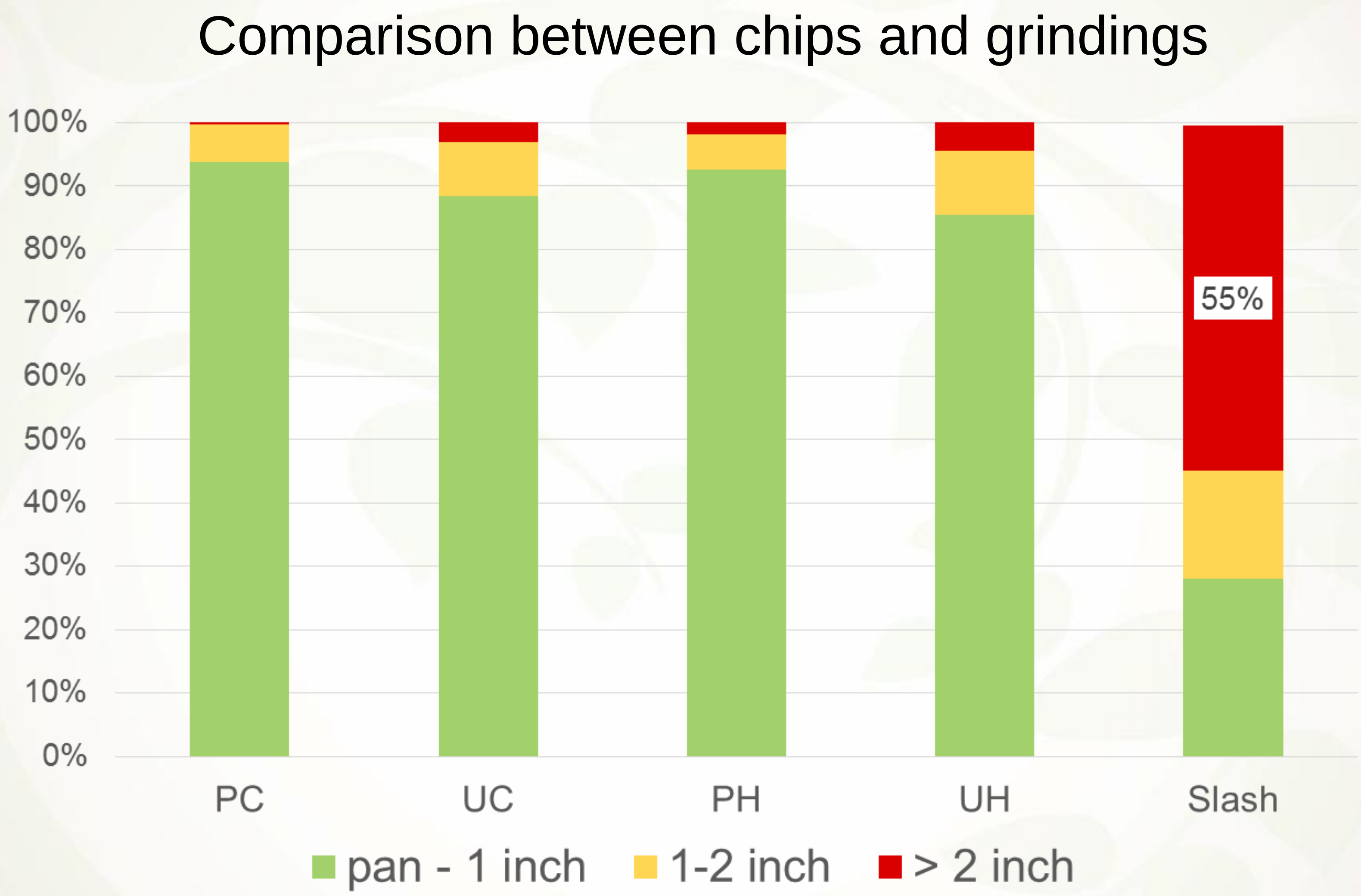
Results

Material type	Particle size (in)	Ash content (%)	Moisture content (%)	Bulk density (lb/ft^3)
Processed conifer	0.68	0.27	26	14.24
Unprocessed conifer	0.72	0.64	27	14.92
Processed hardwood	0.71	1.03	29	20.11
Unprocessed hardwood	0.81	1.07	27	19.34
Slash	1.87	1.50	19	8.57

Results


Particle size distribution
35%
30%
25%
20%
15%
10%
5%
0%
% of total sample
pc
uc
ph
uh
pan - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.5
1.5 - 2
> 2
Size Class (inches)

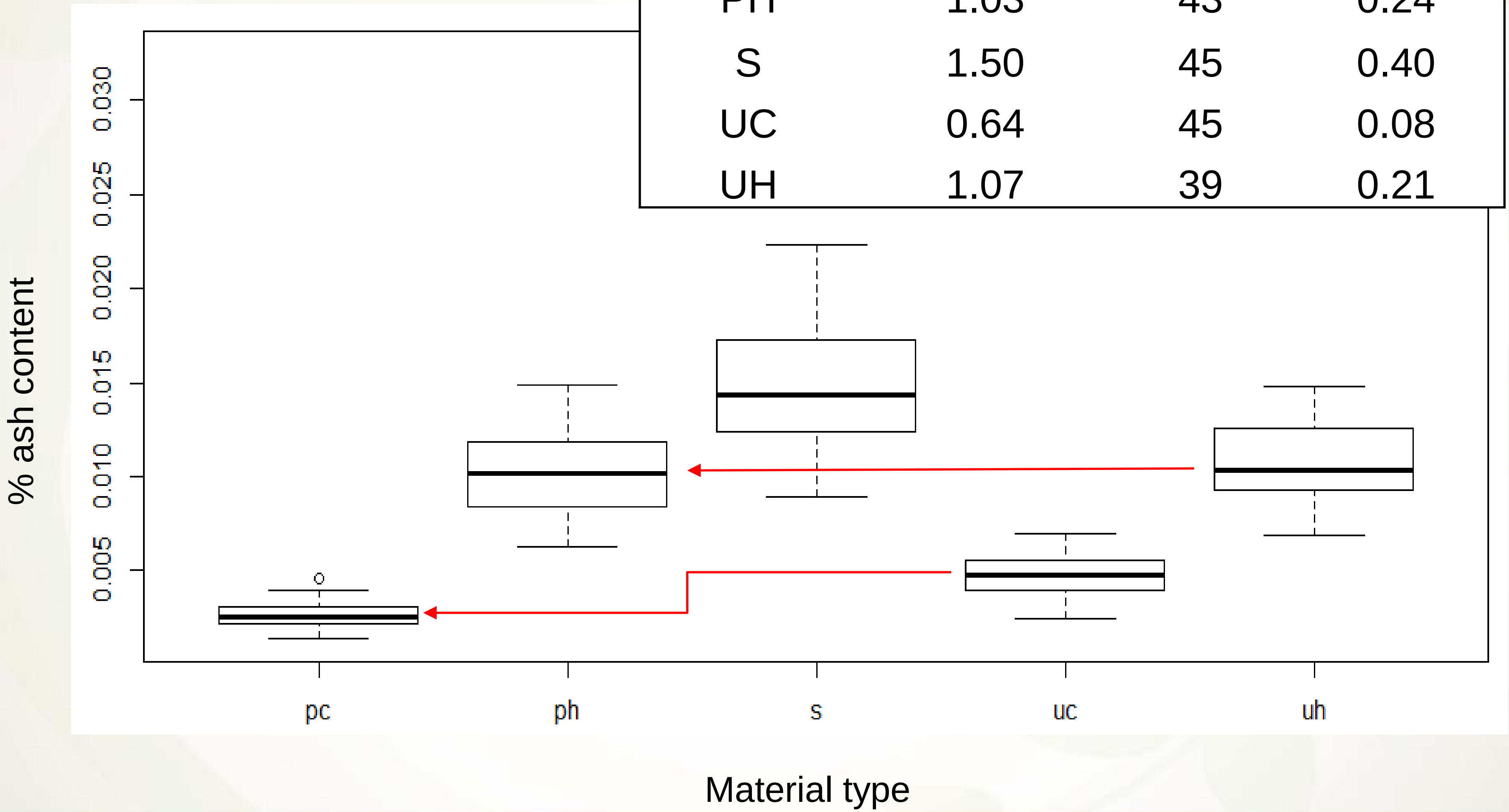
Results


Comparison between chips and grindings
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
55%
PC
UC
PH
UH
Slash
pan - 1 inch
1-2 inch
> 2 inch

Results

Ash content

Material type	Ash content (% dry basis)	n	Standard deviation
PC	0.27	31	0.07
PH	1.03	43	0.24
S	1.50	45	0.40
UC	0.64	45	0.08
UH	1.07	39	0.21



Conclusions

- Sorting stem wood and tops from other residues during a timber harvest operation facilitates the use of a chipper.
- The chipper provided a larger proportion of chips within the target size classes compared to grindings.
- Sorted material produced a feedstock lower in ash content compared to ground slash.
- Through sorting and chipping we were able to improve feedstock quality providing evidence that may justify the additional cost to sort.

Thank You

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Conceptual Specification of Forest Residue Balers

Jim Dooley - Presenter

Chris Lanning

Dave Lanning

Nick Owen

Jason Perry

forestconcepts™

the practice of engineering is as much negotiation and compromise as it is analytic

Louis Bucciarelli

Designing Engineers

Why Bale? Operational Objective:
Enable cost-effective collection of branches & tops

Biomass Baling - Minimize costs for collection, handling, storage, and shipping

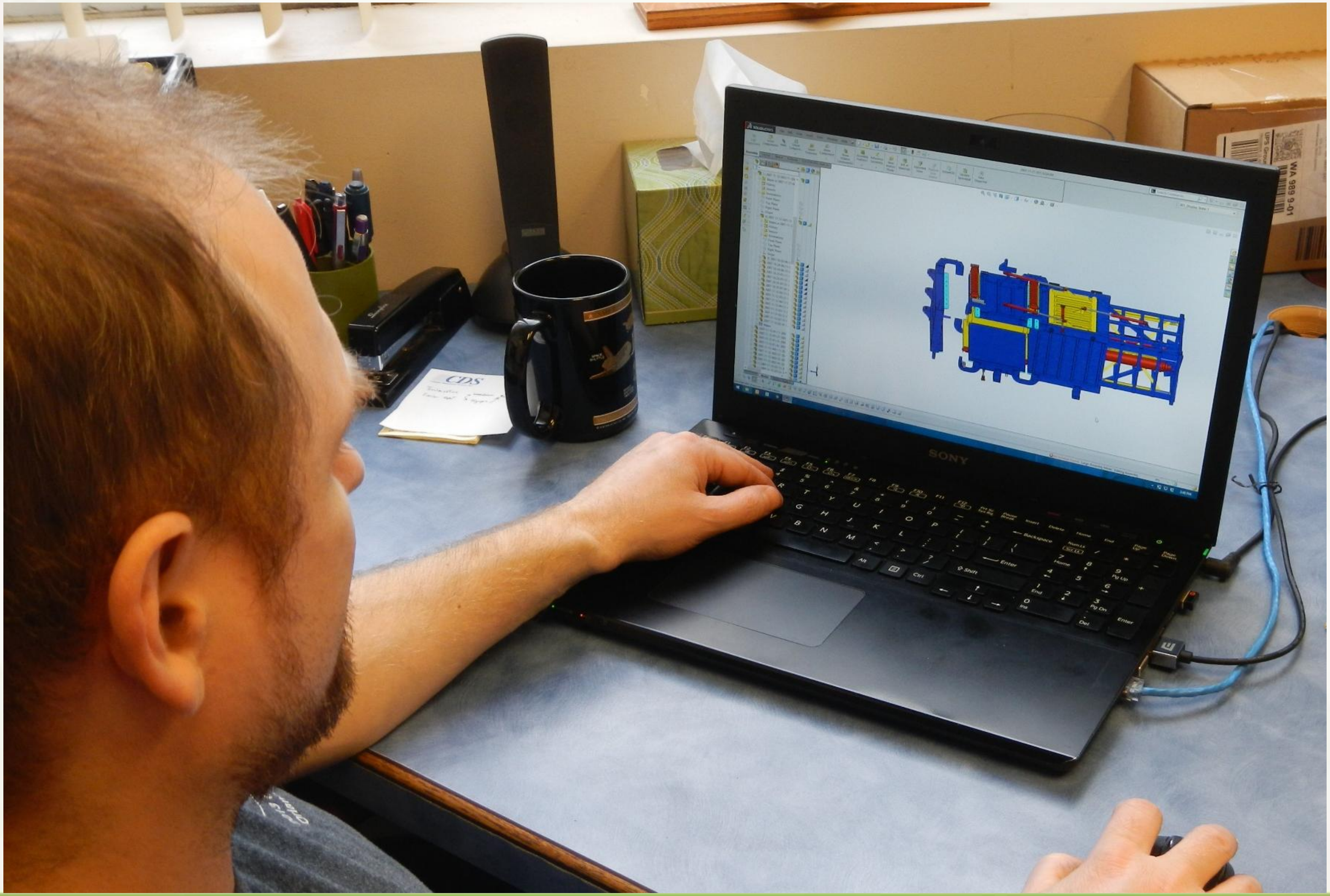
Higher density is better:

- reduces storage space,
- increases transport payload,
- enables more efficient grinding
- Trade-off against heavier baler and more fuel consumption by baler

Rectangular bales are better:

- handling just like other baled recyclables and hay
- use of conventional bale handling equipment
- safer stacking on trucks and in bale-yards

Design of a New Class of Balers



Who Cares? Who's Affected?

Influencers & Constraint Owners	Direct Stakeholders
Landowner / Land Manager Forester/Logging Supervisor Forest Operations Contractor Biomass Hauling Contractor Biomass Bale-Yard Manager Forest Operations Safety Regulator Fire Protection Regulator Invasive Species & Diseases Regulators Insurance Carrier Financial Institution/Credit Provider Environmental Sustainability Interests Bioenergy Advocacy Interests Forest Products Certification Bodies	Baler Owner Baler Operator Baler Mechanic Baler Manufacturer Baler Hauler (mobilization and moving) Equipment Dealer/Parts-Service Provider Bale Hauling Truck Driver Bale Handling Equipment Operator Biomass Grinder Operator

What’s Important to Them?

- Safety – everyone defines safety in their own context
- Cost of ownership and operation
- Bale size, shape, weight, durability, …
- Productivity of baler and “system” in the context of operational requirements
- Bale processing implications with horizontal or tub grinders
- Bale logistics system complexity from logging unit to end user
- Maintenance intensity and complexity
- Noise, dust, …
- Necessary minutia – fuel type, spark arresters, controls, …

Customer Requirements are Bimodal
Need Two Basic Baler Models

Highly mobile & agile system to recover small spatially dispersed piles – 80% of the machines, 40% of the biomass

- 0.3 - 3 tons per pile or roadside windrow
- Piles 10 – 1,000 meters apart
- Objective: Biomass removal at a reasonable cost

High production system for large piles at landings with good truck access – 20% of the machines, 60% of the biomass

- 20 - 200 tons per pile or continuous large windrow
- Biomass forwarders may bring piles from 1-km radius to the baling operation
- Objectives:
  - Highest production rates with low operating cost per ton baled
  - Provide alternative to in-woods grinding and bulk hauling

Other Stakeholder-Driven Top-Level Design Specifications

Minimize operators

- Wireless remote-operate from tracked grapple-loader
- Eliminate ground crew and human chainsaw operators

Minimize cost and time for moving to and within forest

- Physical size does not require oversize load permits
- Gross weight does not require overweight load permits
- Enable transport under a range of contractor operating paradigms

Modular baler unit

- Baler independent of carrier to enable mounting on “anything”
- Forwarder, 6x6 truck chassis, tracked undercarriage, hook-lift frame

Forest Biomass Utility Baler (conceptual)

Modular baler unit that can be mounted to:

- On-road or off-road trailer
- Log forwarder
- Tracked undercarriage
- Truck chassis or flatbed truck
- Hook-lift skid

Bale size and weight optimized for:

- Skid-steer loader handling
- Smaller Peterson* horizontal grinders

Primary uses:

- Baling roadside windrows and supporting thinning crews
- Baling slash from keyhole and stranded landings
- Recovering dispersed slash

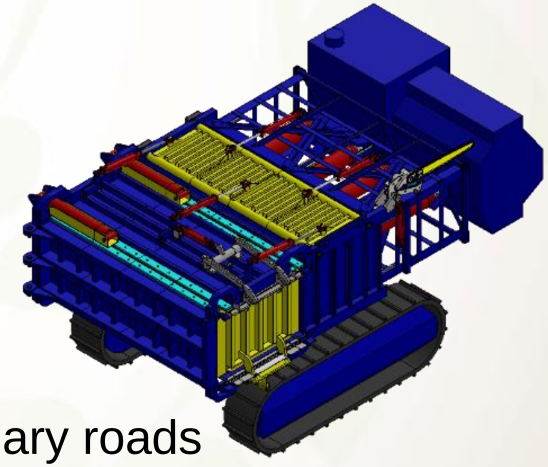
Forest Biomass Large Baler (conceptual)

Modular baler unit that can be mounted to:

- Tracked undercarriage
  - remote-operated by loader)
- Off-road/mining truck chassis
- Log forwarder
- On-road or off-road trailer

Bale size and weight optimized for:

- Track-hoe and off-road forklift handling
- Largest Peterson* horizontal grinders



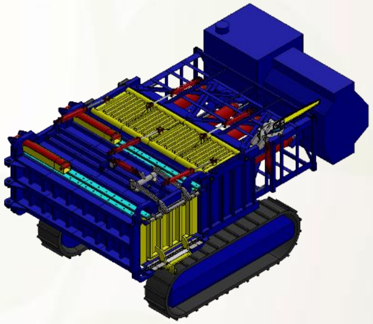
Primary uses:

- Baling piled slash at cable and ground logging sites
- Baling dispersed slash piles within units and secondary roads
- As an alternative to in-woods grinding

Conceptual Forest Residuals Balers

(Updated October 1, 2015)

			Conceptual BRDI Project Balers	
	FCLLC Engineering Prototype (FCEP)	Urban Chipper Replacement	Forest Biomass Utility Baler	Forest Biomass Large Baler
Bale Size (inches)	32x48x56	36x48x72	32x48x56	34x48x96
Bale Density (lb/cu.ft – @ 50% MC wb)	15-25	15-20	20-30	20-30
Bale Weight (lb)	800 – 1,400	1,000 – 1,400	1,000 – 1,500	2,000 – 2,700
Loader	Self-loading grapple	Self-loading grapple	Self-loading grapple	Track-hoe with brush grapple
Theoretical/Operational Capacity (bales/hr)	3/2	5/3	10/4	18/10
Horsepower	28	49	49	260
Crew	2 (manual tie)	2 (manual tie)	1 (auto-tie)	0 (remote-operated)
Running Gear	5th Wheel Trailer	Category 3 trailer	Modular	Tracked
Capital Cost ($) Est.		$110,000	$130,000	$350,000



Jim Dooley

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Thank You

www.forestconcepts.com

*** Peterson is a brand of Peterson Pacific Corporation**
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