USDA Bioenergy Feedstock Workshop – October 2011

Beneficiation of Chipped and Shredded Woody Biomass

Cleaning “dirty” biomass to produce quality feedstocks

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Jim Dooley

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USDA United States Department of Agriculture National Institute of Food and Agriculture

Agenda

- Forest Concepts – Supply Chain R&D
- Woody Biomass Availability and Competition
- Characterization of Low-Grade Woody Biomass
- Pathways to Achieve User Specifications
- Results and Discussion
- Final Thoughts

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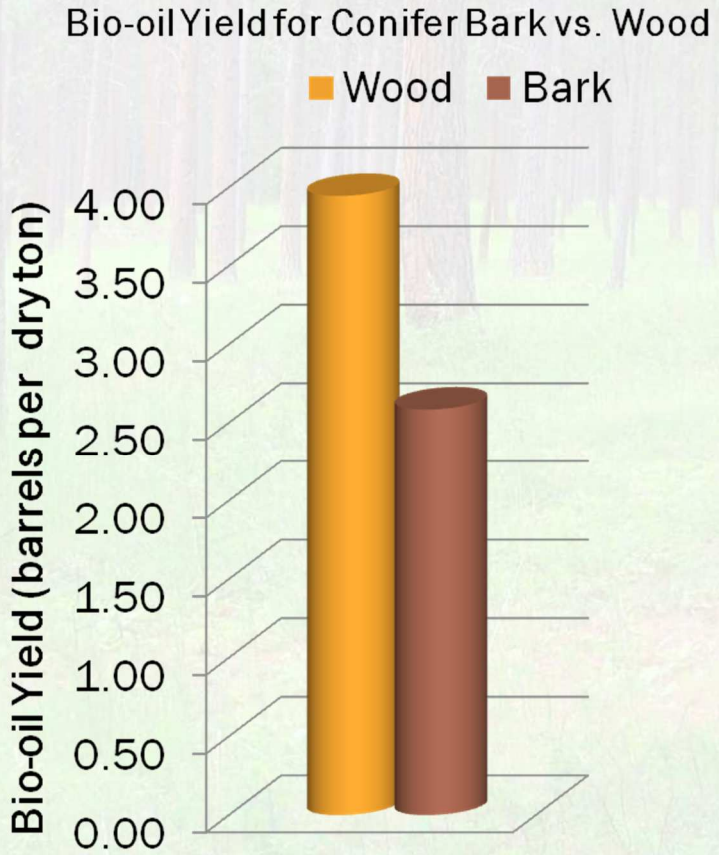
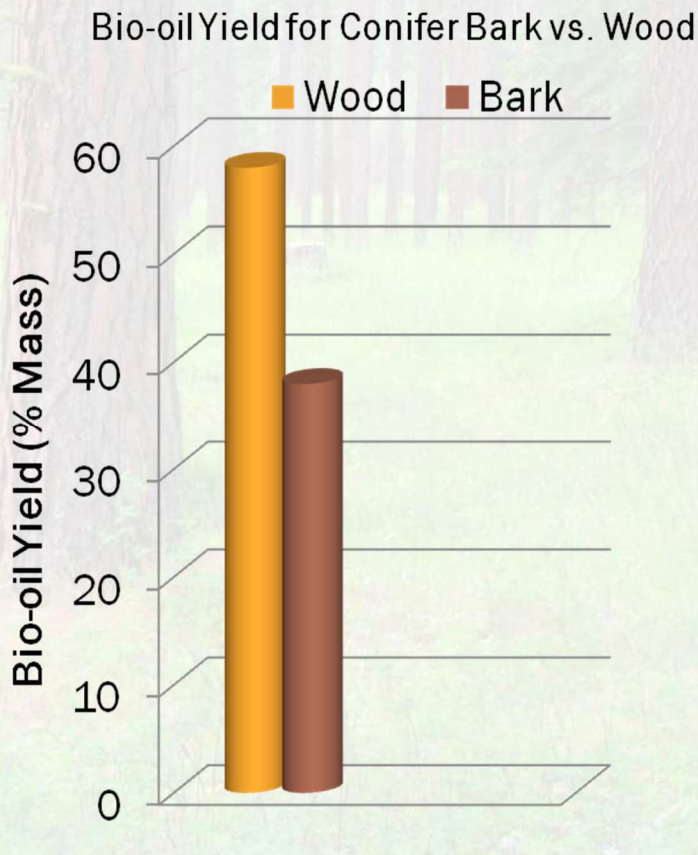
Biomass Feedstock Quality Matters

- Ash content is a major issue for pellet fuel feedstocks
- Soluble minerals (e.g. alkanes, iron oxide, calcium carbonate, sodium, postassium, …) greatly reduce yield of biofuels due to catalytic reactions
- Particle size and surface-to-volume ratios affect reaction kinetics, drying rates, materials handling, …
- Quality can be improved by:
  - Anatomical fractionation (bark, leaves, …)
  - Cleaning to remove soil, gravel, metal, grit, …
  - Washing to reduce extractives
  - Size sorting
  - Comminution methods and equipment

Bio-oil yield for Bark vs Wood





Manuel Garcia-Perez 2009

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Feedstock Sieve Size by Source and Use

$4 / ton → Grinding Cost → $80 / ton

Sieve Size - Retained sieve – mm (sieve)	Hog fuel for Stoker-Grate Boilers	Large Scale Gasifiers	Wood Chips	Mini Chips	Small Downdraft Gasifiers	Bio-chemical hydrolysis	Fluidized bed wood bio-power	Auger Fast Pyrolysis	Micro Chips	Fuel Pellets	Fluidized Bed Fast Pyrolysis	Coal Co-firing	Kilns & oil fired burners
100 (4 in)													
75 (3 in)													
50 (2 in)													
25 (1 in)													
19 (3/4)													
12 (1/2)													
9 (3/8)													
6 (1/4)													
4 (3/16)													
3 (1/8)													
2 (No. 10)													
1 (No. 20)													
0.5 (No 35)													
0.2 (No. 100)													
0.1 (No. 200)													
.05 (No 325)													

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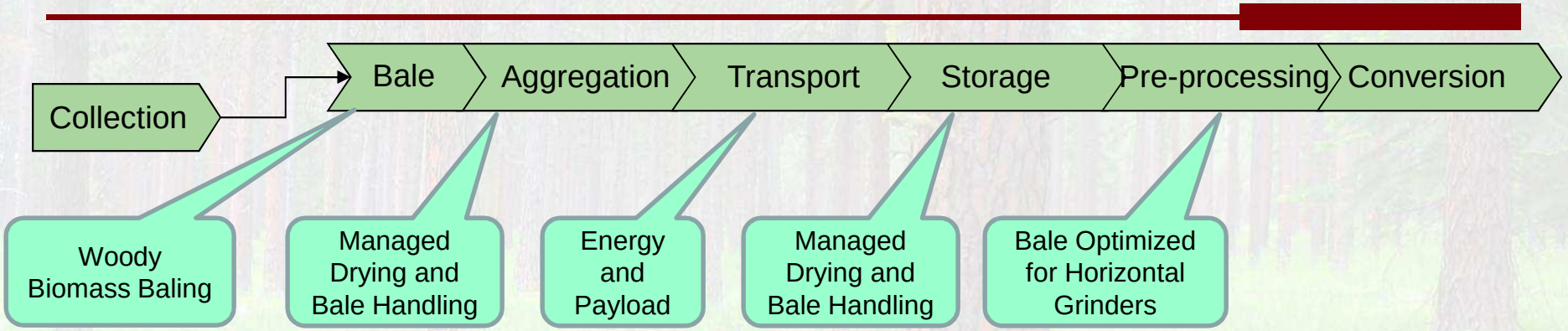
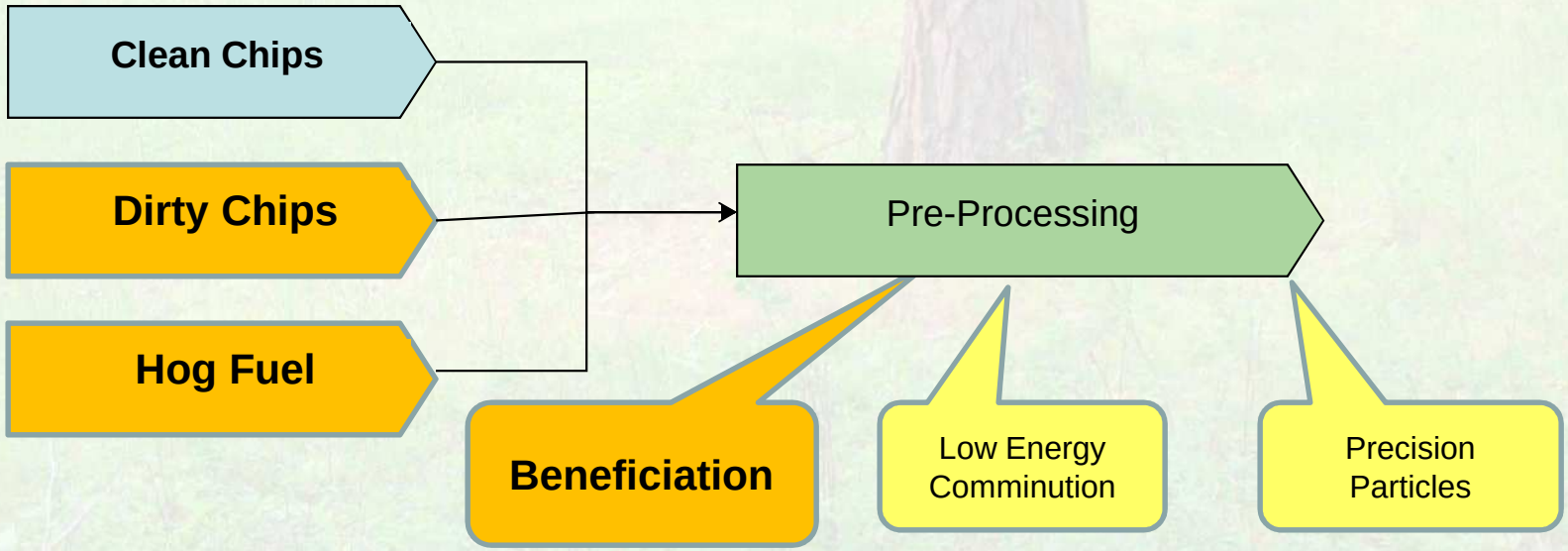
Biomass Supply Chain & Forest Concepts





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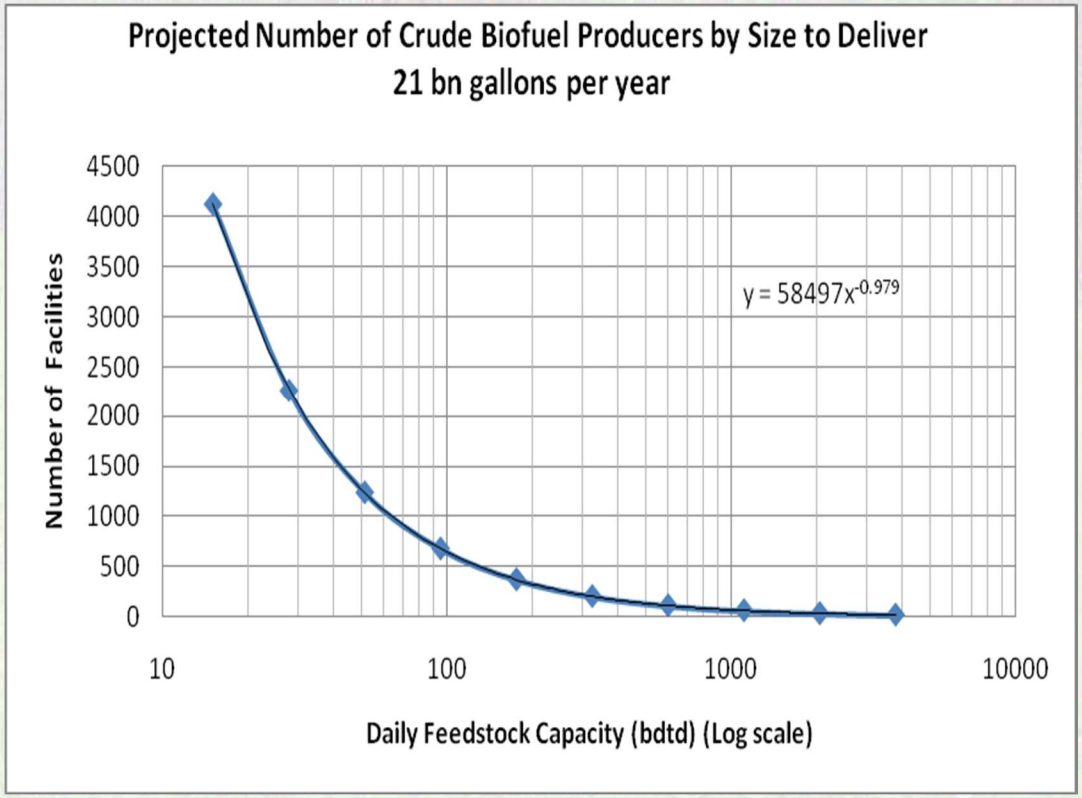
Bioenergy Science and Technology at Forest Concepts

Our Innovations –

- Reduce the cost of collection, handling and transport for woody biomass
  - Baled biomass is less expensive to make, store, and transport than chips
- Increase the volume of cost-effective cellulosic biomass in the market
  - Baled biomass can be handled and trucked just like other recyclables
  - Beneficiation and cleaning of low-grade and off-spec biomass
- Increase the yield of liquid transportation fuels
  - Feedstock cleaning and sorting improves conversion efficiency
  - Crumbles™ precision particles increase yield
- Increase the net energy of biofuels
  - Reducing energy consumption through the feedstock supply chain
  - Low energy comminution saves energy and provides more uniform particles
  - Reduced process time saves energy in the conversion facilities
- Reduce the capital and operational cost of conversion facilities
  - Crumbles™ precision particles reduce process time
- Enable competitive production of biofuels at smaller-scale facilities
  - Appropriate scale equipment designs
  - Scalable technologies based on sound science

Power Curve Distribution (aka Axtel Distribution) of Firms by Size

- Most industries in the developed world are comprised of a mix of very small to very large facilities.
- In the dairy industry there are more than 50,000 of dairies with less than 100 cows and a only about 500 dairies with more than 2,000 cows according to USDA.
- In the sawmill industry there are more than 2,000 sawmills with less than 10 employees and only 27 with more than 500 employees according to the US Census Bureau.
- Sawmills and dairies are somewhat analogous to the emerging second generation biofuels industry.



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Dooley 2011 Conceptual Distribution of Primary Biofuel Producers by Size – White Paper. Forest Concepts, LLC

Conceptual Number of Primary Producers by Amount of Biomass Converted per Day

size bdtd feedstock	number of producers	gal/day/ facility	Class aggregate million-gal/year
15	4,128	1,500	1,486
28	2,260	2,775	1,505
51	1,238	5,134	2,160
95	678	9,497	2,188
176	371	17,570	2,217
325	203	32,505	2,246
601	111	60,134	2,275
1112	61	111,248	2,305
2058	33	205,809	2,335
3807	18	380,747	2,365
Total	9,102	-	21,082

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Dooley 2011 Conceptual Distribution of Primary Biofuel Producers by Size – White Paper. Forest Concepts, LLC

Biomass → Feedstock












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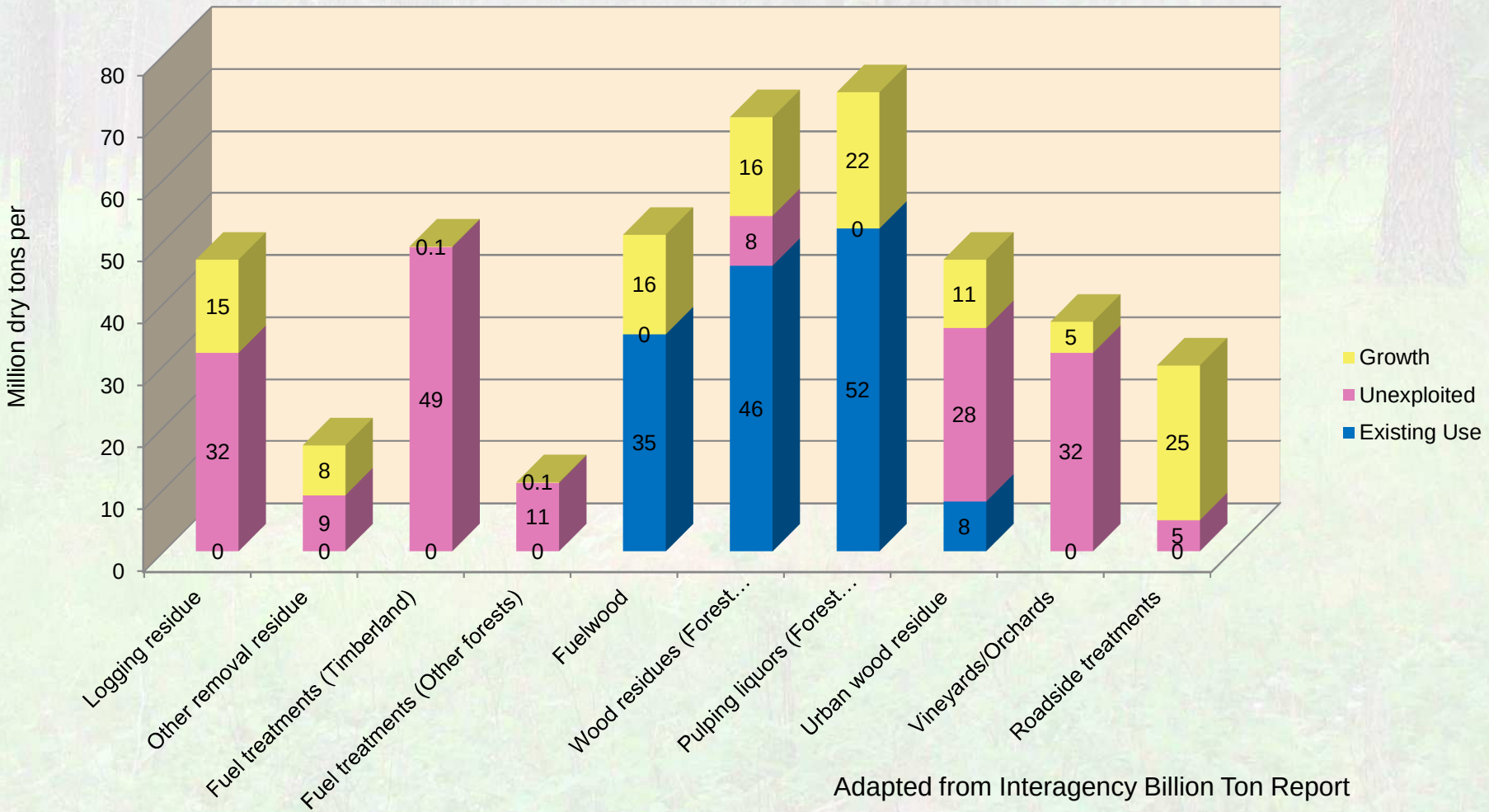
Availability of Woody Biomass in the U.S.



Adapted from Interagency Billion Ton Report

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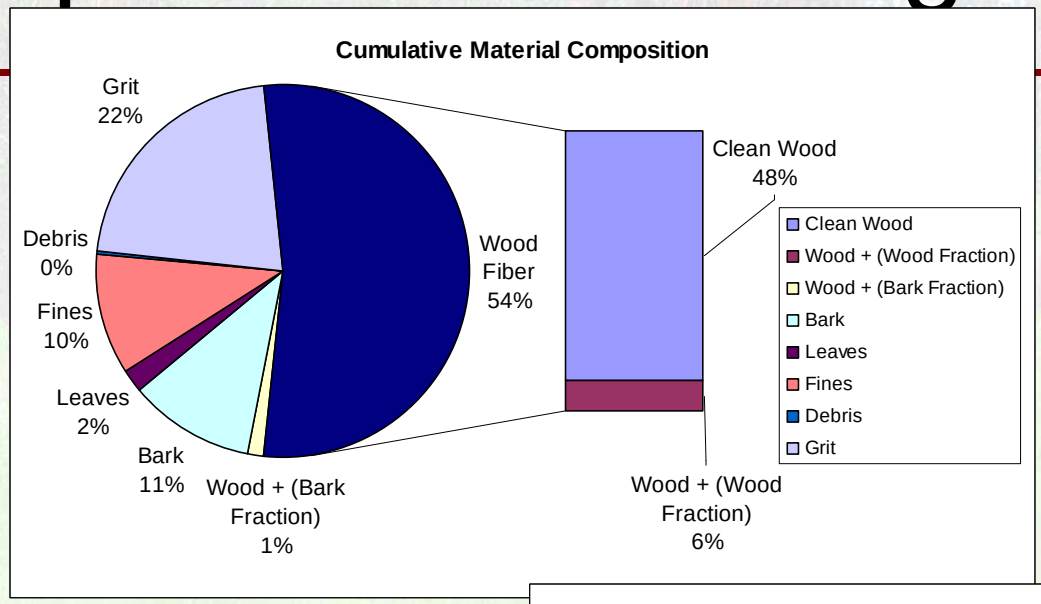
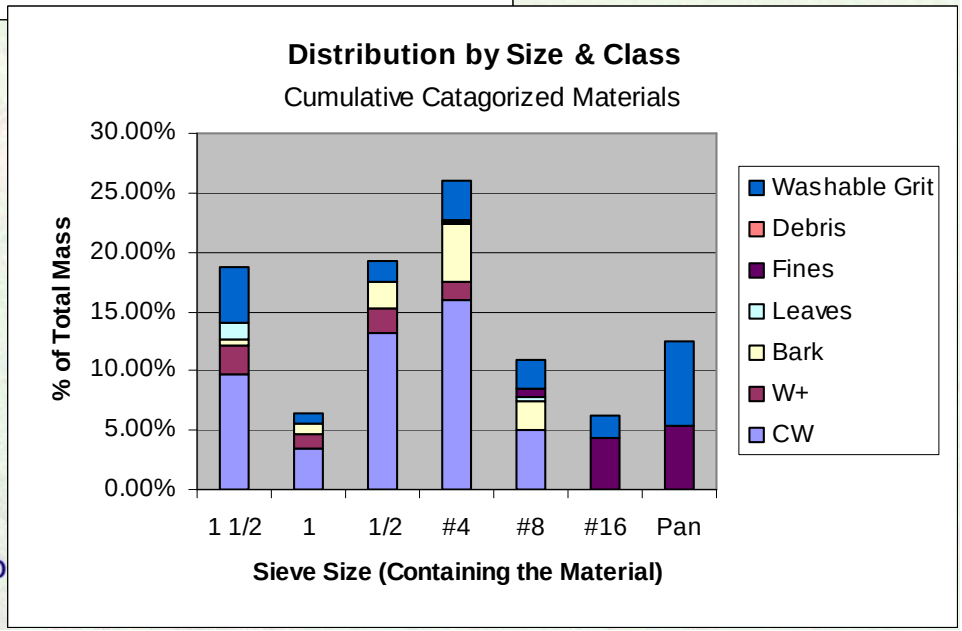
The problem with Hog Fuel

- Dirt and grit
- Bark
- Fines
- Overs



100 million tons per year available



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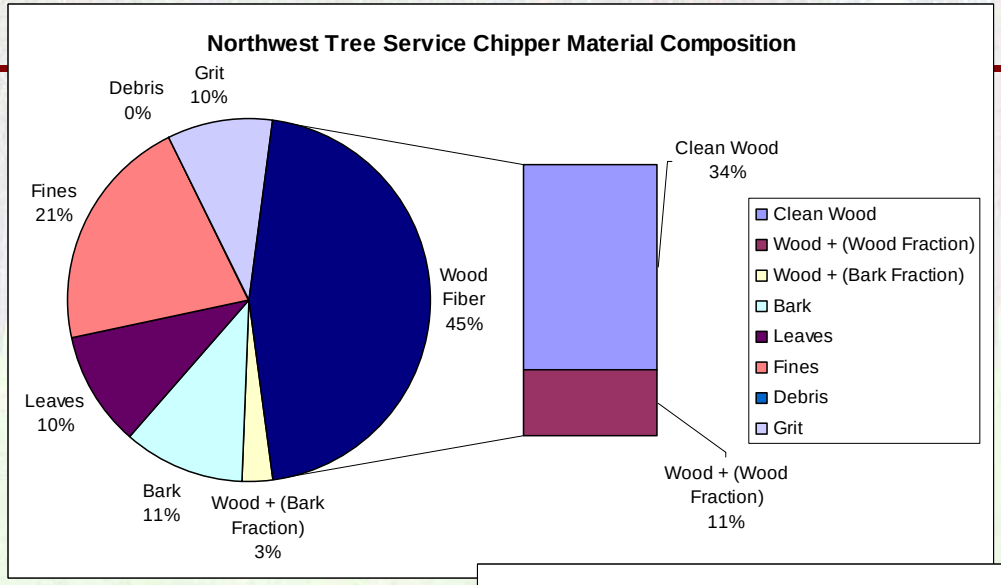
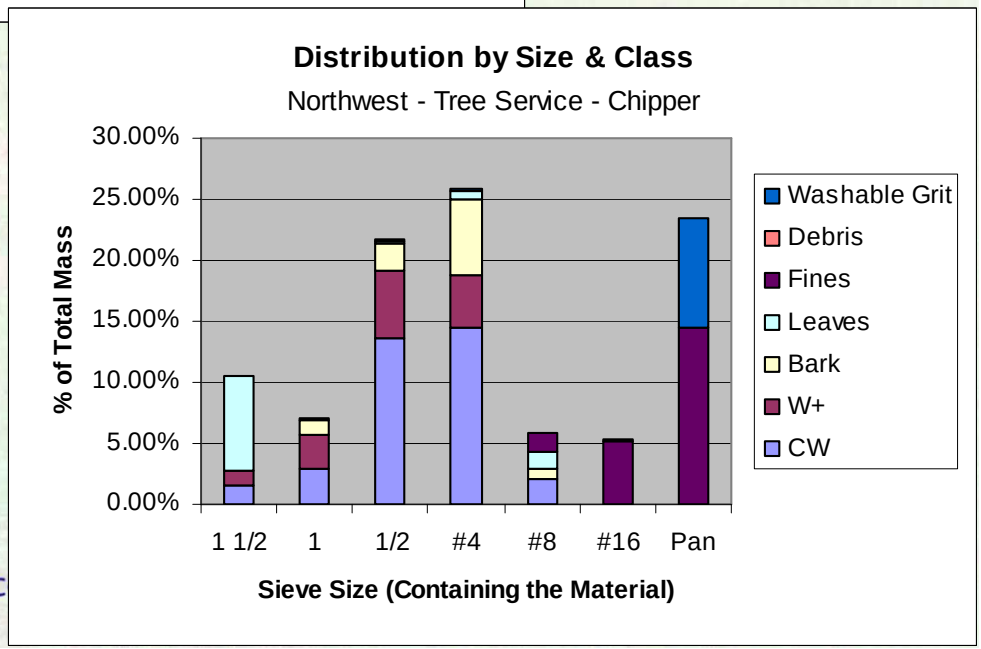
The problem with Urban Chips

- Dirt and grit
- Bark & Leaves
- Fines



50 million tons per year available



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Woody Biomass Beneficiation

USDA SBIR Objective:

Increase the supply of wood fiber to reduce conflicts and competition for traditional mill residuals – This was 3 years before BCAP!

Develop technologies to reprocess hog fuel and urban chips into fractions suitable to replace traditional mill residuals

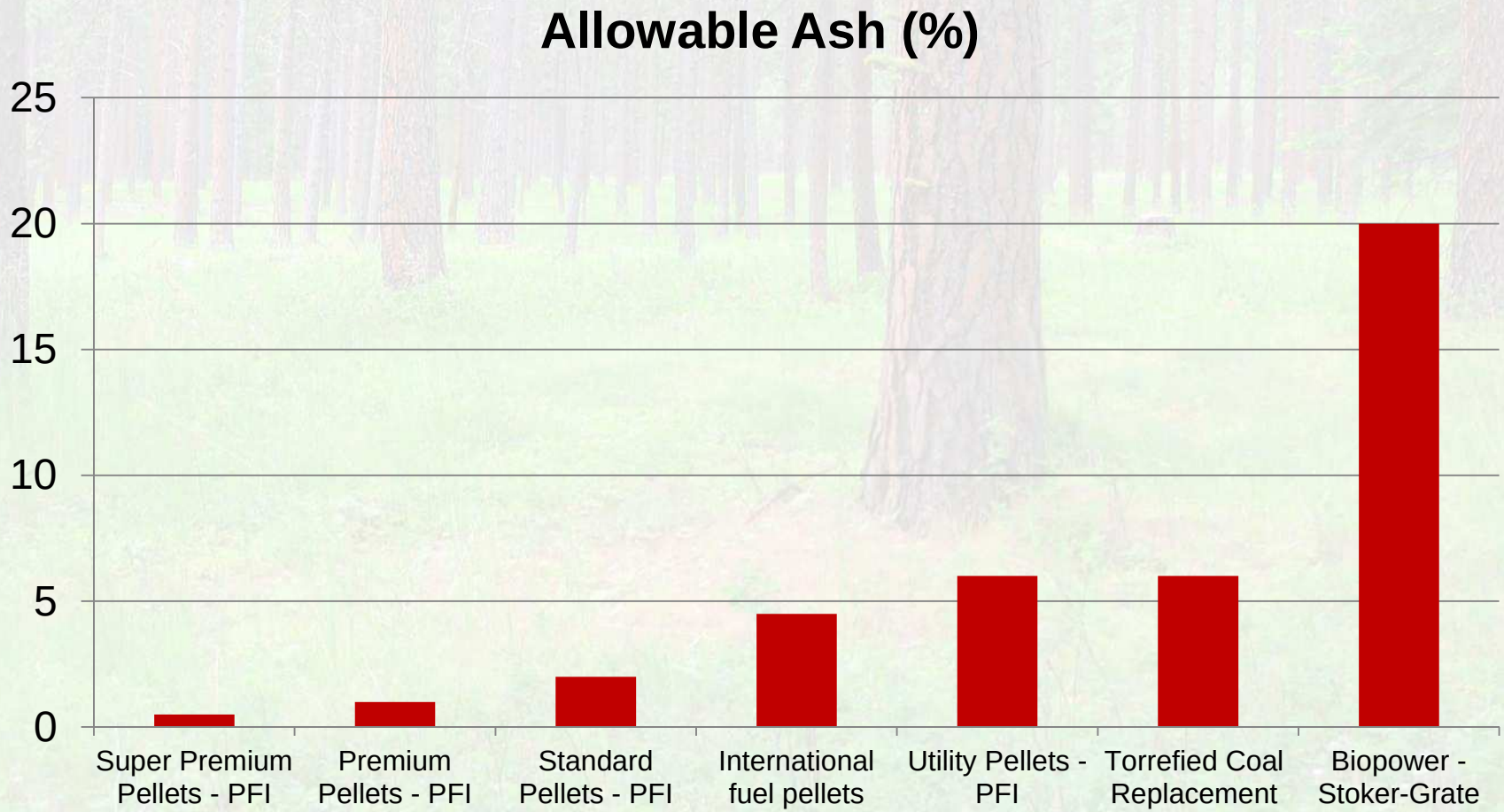
- Reduce bark content to 1, 3, or 6 % targets
- Deliver clean streams of wood and bark that meet industry sector standards for ash and grit content

http://bioenergy.ornl.gov/papers/misc/biochar_factsheet.html

Ash Content of Clean Biomass Feedstocks

	CHEMICAL CHARACTERISTICS				
	heating value (gross, unless specified; GJ/t)	**ash** (%)	**sulfur** (%)	**potassium** (%)	**Ash melting temperature** [some ash sintering observed] (C)
corn stover	17.6	5.6			
sweet sorghum	15.4	5.5			
sugarcane bagasse	18.1	3.2-5.5	0.10-0.15	0.73-0.97	
sugarcane leaves	17.4	7.7			
hardwood	20.5	0.45	0.009	0.04	[900]
softwood	19.6	0.3	0.01		
hybrid poplar	19.0	0.5-1.5	0.03	0.3	1350
bamboo	18.5-19.4	0.8-2.5	0.03-0.05	0.15-0.50	
switchgrass	18.3	4.5-5.8	0.12		1016
miscanthus	17.1-19.4	1.5-4.5	0.1	0.37-1.12	1090 [600]
Arundo donax	17.1	5-6	0.07		

Allowable Ash by End Use



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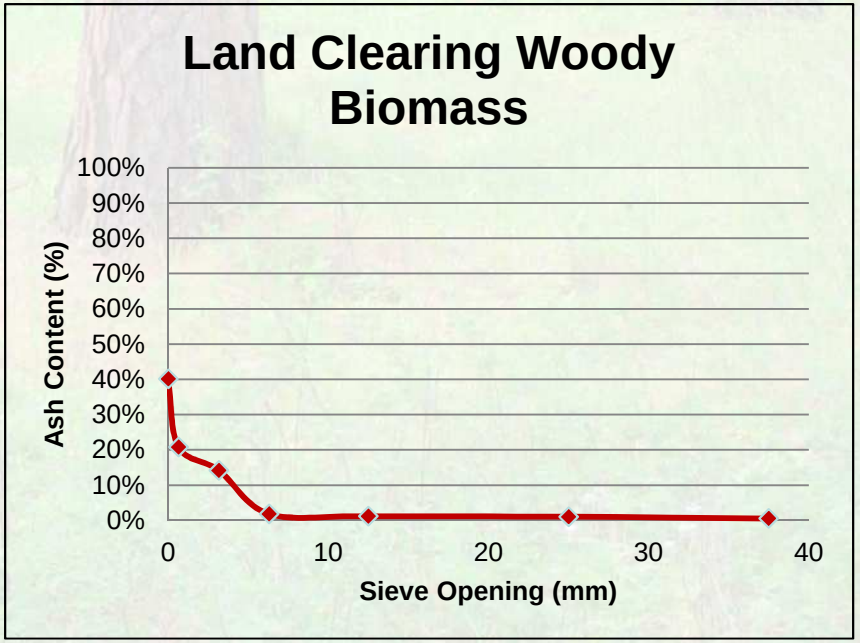
Ash Content by Sieve Fraction for Land Clearing Woody Biomass

Sample: 2011.07.12.001		
Sieve ID	Opening (mm)	Ash Content
3	75.0	0.5%
1 1/2	37.5	0.56%
1	25.0	1.07%
1/2	12.5	1.21%
1/4	6.3	1.86%
1/8	3.2	14.21%
No. 16	0.7	20.82%
Pan		40.11%

Note: Clean wood is ~ 0.3% ash



SBIR Beneficiation Validation Test

Ground Land Clearing Debris - Seattle

Mass

100%

Pile

66 % Wood
13 % Bark
21 % Other
12.3 % Ash

67%

Initial Screen

80 % Wood
13 % Bark
7 % Other
2.1 % Ash

60%

Dry Flail

67 % Wood
15 % Bark
18 % Other
1.4 % Ash

61%

Wet Flail

77 % Wood
11 % Bark
13 % Other
1.1 % Ash

Floatation Tank

79% Wood
18 % Bark
3 % Other
0.6 % Ash

57%

Final Screen

Note: This experiment sought to minimize ash while maximizing total biomass retained. Thus, the bark content was higher than we wanted. Removing more bark would substantially reduce the mass yield of clean biomass.

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Ground Land Clearing Debris
Sample: 2011.07.12.001
After Wet Flail
77 % Wood
11 % Bark
1.1 % Ash
Raw Material
66 % Wood
13 % Bark
12.3 % Ash

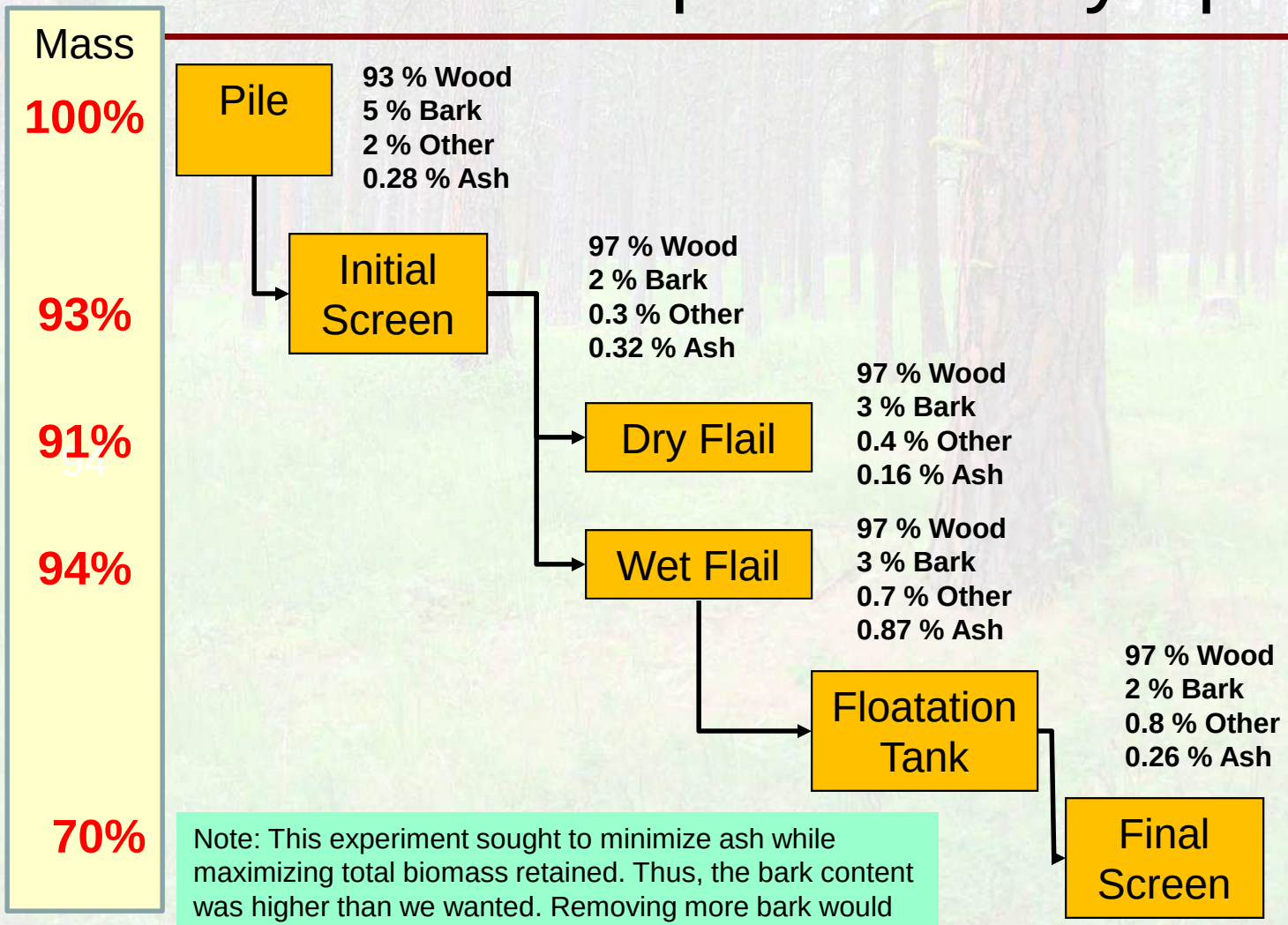
Ash Content by Sieve Fraction for Clean Wood Chip Fuel – Olympic Region

Sample: 2011.07.14.001		
Sieve ID	Opening (mm)	Ash Content
3	75.0	-
1 1/2	37.5	-
1	25.0	0.26%
1/2	12.5	0.24%
1/4	6.3	0.26%
1/8	3.2	0.3 4%
No. 16	0.7	0.34 %
Pan		2.93 %

Note: Clean wood is ~ 0.3% ash

SBIR Beneficiation Validation Test

Clean Wood Chip Fuel – Olympic Region



Note: This experiment sought to minimize ash while maximizing total biomass retained. Thus, the bark content was higher than we wanted. Removing more bark would substantially reduce the mass yield of clean biomass.

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Ash Content by Sieve Fraction for Urban Arborist Chips – Auburn, WA

Sample: 2011.07.19.002		
Sieve ID	Opening (mm)	Ash Content
3	75.0	-
1 1/2	37.5	-
1	25.0	-
1/2	12.5	1.9 %
1/4	6.3	2.8 %
1/8	3.2	3.8 %
No. 16	0.7	4.4 %
Pan		6.0 %

Note: Clean wood is ~ 0.3% ash

SBIR Beneficiation Validation Test

Urban Arborist Chips – Auburn, WA

Mass	
100%	Pile: 26 % Wood, 22 % Bark, 52 % Other, 3.2 % Ash
43%	Initial Screen: 48 % Wood, 20 % Bark, 32 % Other, 2.6 % Ash
27%	Dry Flail: 65 % Wood, 22 % Bark, 13 % Other, 2.6 % Ash
34%	Wet Flail: 59 % Wood, 23 % Bark, 18 % Other, 2.4 % Ash
na	Floatation Tank → Final Screen

Note: This experiment sought to minimize ash while maximizing total biomass retained. Thus, the bark content was higher than we wanted. Removing more bark would substantially reduce the mass yield of clean biomass.

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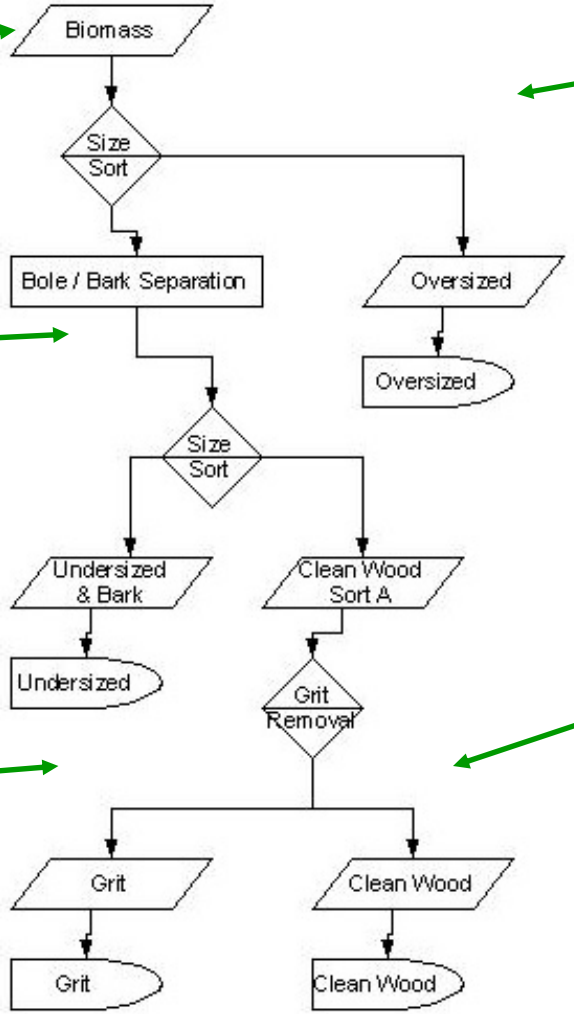
Conclusions from Validation Tests

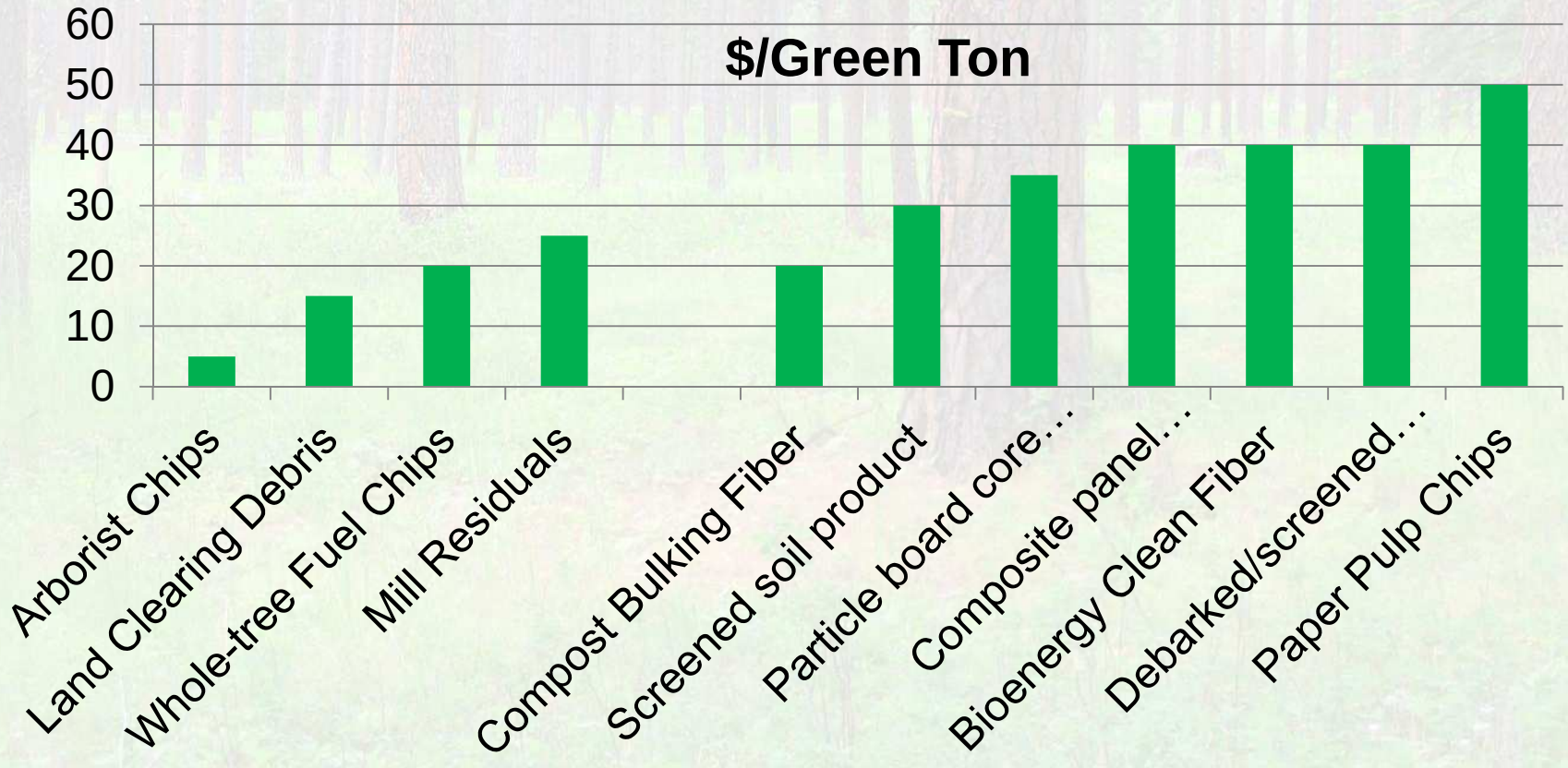
- Land Clearing Debris
  - Screening alone can often get the ash content below 3%
  - Dry or wet flail processing can further reduce ash to less than 1.5%
  - Bark content was not appreciably reduced – More work to be done!
  - Approx. 60% of mass could be redirected to fuel pellets or furnish
- Arborist Ponderosa Pine Chips
  - Screening and dry flail increased wood content from 26% to 65%
  - More than 65% of mass was removed by processing
  - Total ash remained approx. 2.5% throughout testing
  - This sample would be uneconomical to upgrade
- Fuel Chips
  - This material was very clean (0.3% ash) to begin with
  - Processing may reduce bark from 4.6% to 2.7%

SBIR Validation System



Value Chain (Northwest Fall 2011)

NOTE: All biomass pricing is local, seasonal, and competitive!



Final Thoughts

- Most woody biomass does not meet user needs for dirt, ash, bark, and rocks
- Beneficiation can occur at producer, depot/aggregator, or user
- Cost is a function of the degree of cleaning needed
- Methods are applicable to cane, corn, …
- Forest Concepts' demonstration scale portable system is available for use – 1 bdt per hour

Thank You

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