Emerging Technologies to Improve Preparation of Woody Biomass for Pretreatment and Conversion

Jim Dooley, CTO – Forest Concepts

April 29, 2014 - Northwest Wood-Based Biofuels + Co-products Conference

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Forest Concepts was ranked by *Biofuels Digest* as one of the 150 top biofuels industry firms in the world in 2012

forestconcepts™

- Formed in 1998
- Eight full-time regular employees
- Based in Auburn, WA – global network of collaborators
- A technology developer at the intersection of biology, engineering, and enterprise
  - Bioenergy – Crumbles®, Baling, Beneficiation, Precision Feedstocks
  - Environmental Restoration – ELWd™ and WoodStraw®
  - Community-scale enterprises

Roadmap to Talk

- What?
  - What are the objectives?
- How?
  - Who is doing interesting work
  - A few featured innovations
- Big-deal Open Questions!

What? - Objectives

- Reduce the cost of collection, handling and transport of woody biomass
  - The PRICE of raw biomass is dominated by the logistics costs, not payments & profits to the grower
  - Reduce waste and losses downstream that effectively increase feedstock costs
- Increase the volume of cost-effective cellulosic biomass in the market
  - Half or more of the "available" woody biomass is deemed not economical or undesirable
    - Land clearing debris, urban greenwood, fuel reduction thinnings, tops and branches, infrastructure vegetation management…
- Increase the yield of liquid transportation fuels
  - Feedstock cleaning and sorting improves conversion efficiency
  - Particle optimization can improve yields (size, shape, surface, moisture content, …)
  - Reduce waste streams and losses that are a consequence of feedstock qualities
- 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 processing time saves energy in the conversion facilities
- Reduce the capital and operational cost of conversion facilities
  - Reduce pretreatment and conversion time in unit operations
  - Eliminate feedstock properties that decrease catalyst life, increase separations costs, and increases yield
- Enable competitive production of biofuels at smaller-scale facilities
  - Appropriate scale equipment designs
  - Scalable technologies based on sound science
  - Understand and capitalize on discontinuities in scaling factors

How? – Innovations

- Reduce the cost of collection, handling and transport of woody biomass
  - Decision support tools and operational systems optimization
  - Merchandising strategies that add value and reduce costs
  - Increasing transportation bulk density, and “reactable content” payloads
  - Minimize consumption of fossil fuels – optimize where energy is invested
- Increase the volume of cost-effective cellulosic biomass in the market
  - Change form of what is hauled – eg. Baling versus ground materials
- Increase the yield of liquid transportation fuels
  - Beneficiation
  - Precision Comminution
  - Moisture Control, avoidance of dryness-induced recalcitrance
  - Freshness
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Needed Supply Chain Innovations

- Reduce the cost of collection, handling and transport of woody biomass
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- Increase the volume of cost-effective cellulosic biomass in the market
  - Baled biomass can be handled and trucked like any other recyclable
  - Beneficiation and cleaning of low-grade and off-spec biomass
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  - Crumbles® precision particles reduce processing time
  - Low ash feedstocks improve catalyst life, reduce separations costs, and increases yield
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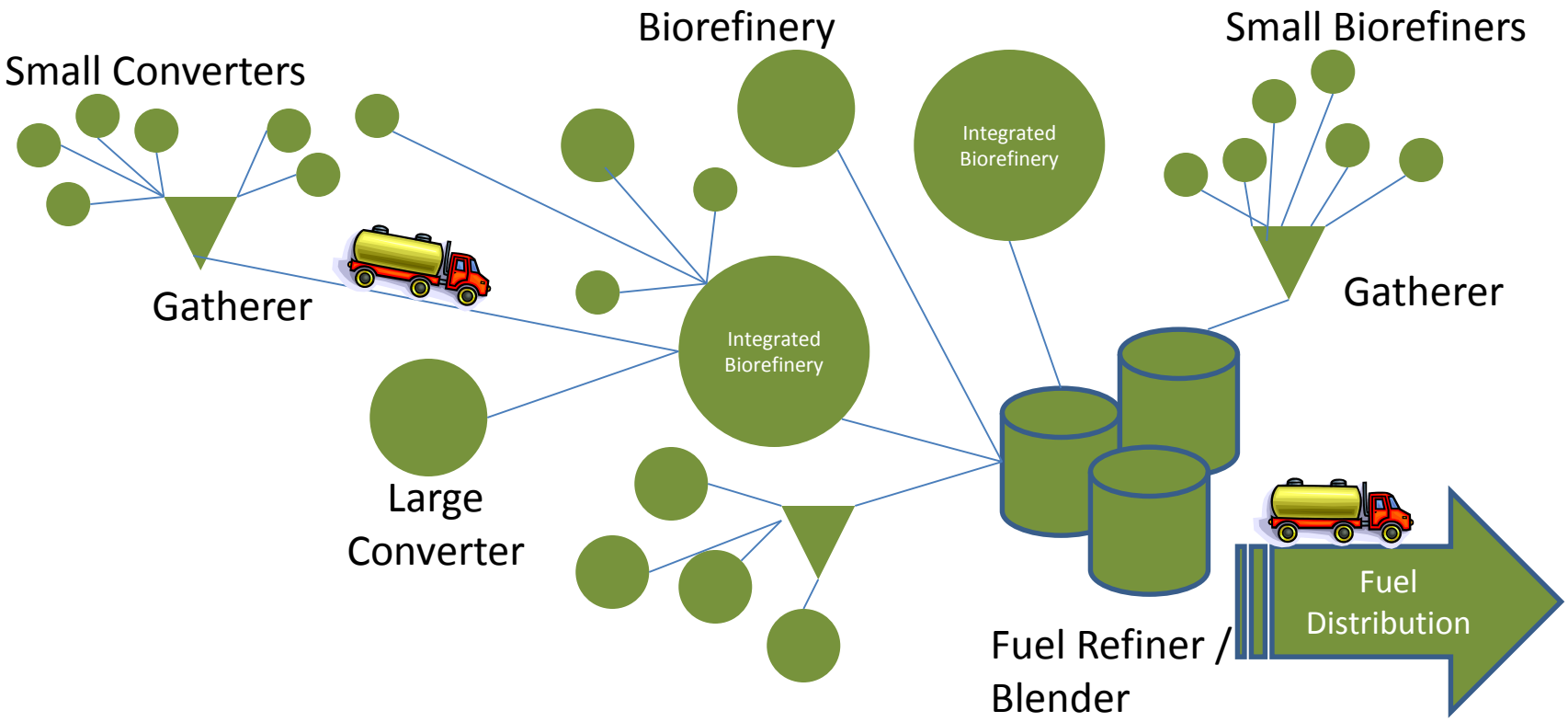
Distributed Production of Biofuels

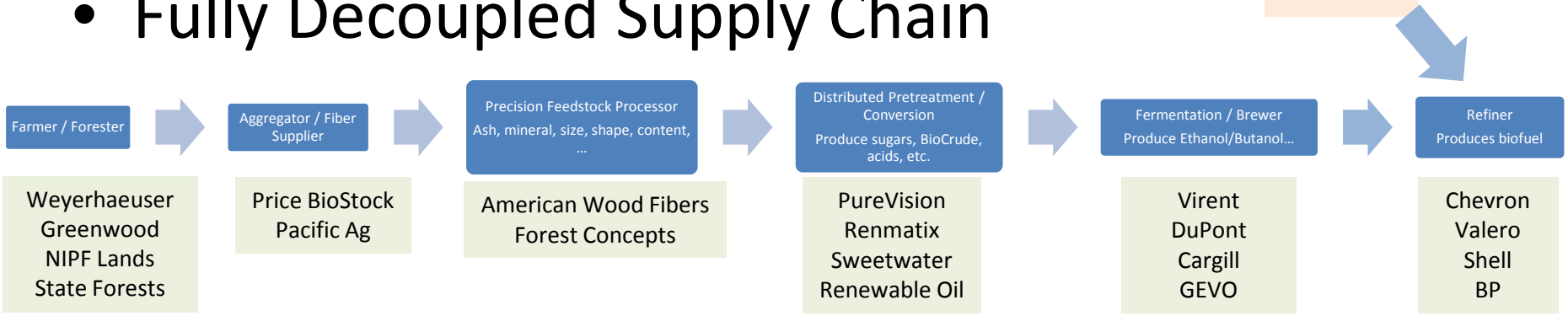


Biofuel Supply Chain

- Integrated Biorefinery
  - Receives pellets, logs, bales, land clearing debris, etc.
  - Ships biofuel blend-stock to petroleum distributors

POET
Abengoa
Blue Fire
ZeaChem
GEVO
KiOR
LS9
Fulcrum
Ensyn
Rentech

- Fully Decoupled Supply Chain



UM and RMRS Operations Research
Woodam Chung & Nate Anderson

2011-2015 BRDI Project

- Whole-tree clean, microchip production at Tricon Timber, LLC
- Prototype equipment fabrication with Jump Trucking, Inc.
  - High speed mobile grinder
  - Nested, high mobility trailer system
- Biochar pelletization and skidder mounted pellet spreader (with Englund, Windell, Page-Dumroese)

UM and RMRS Operations Research
Woodam Chung & Nate Anderson

2013-2018 BANR Project

- New allometric equations for beetle-killed log and biomass yield
- Operations research in beetle kill salvage in the Rocky Mountains
- Tractor equipment sized for biomass harvest on NIPF (with Rob Keefe, UI)

Greg Forbes and Rodrigo Olave,
Agri-Food and Biosciences Institute, Northern Ireland
Michael Fairgrieve and Brian Wilson,
Forest Service of Northern Ireland.

During operation logging residues (brash) were arranged in several different formats to facilitate a baling machine to bale the brash. Bales (and logs) were drawn off and stacked at roadside.

During the next two years brash and logs were chipped using a large mobile chipper into tractor drawn silage trailers. Produce was transported approximately one mile to the on-farm drying sheds & tipped in.

Conclusions,
The use of industrial grade chipper with farm transports in a short distance delivery chain produced fuel quality woodchips from brash at a cost ~ 50% less than local market woodchip. Low transport costs were the primary financial element in achieving this low price. Logistical planning was found to be the key factor for efficient production.

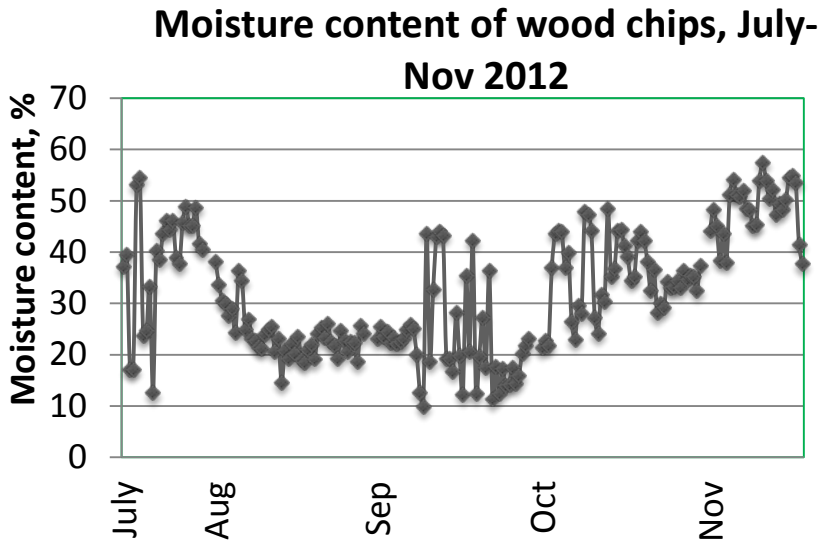
Shahab Sokhansanj
University of British Columbia

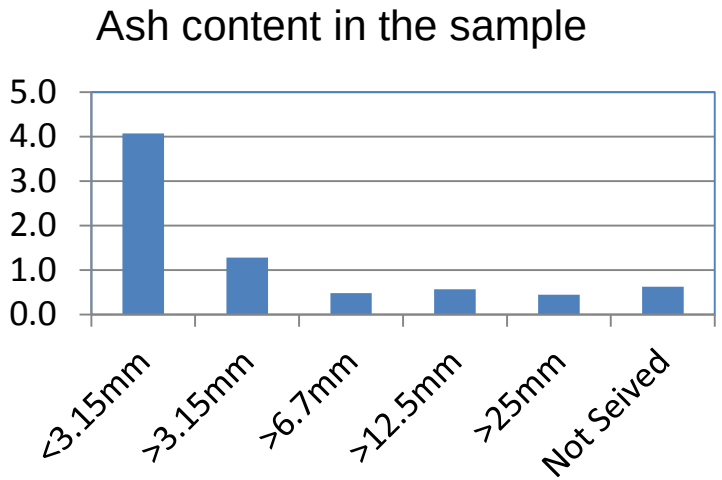
CERC Clean Energy Research Centre

BBRG BIOMASS.UBC.CA

Wood chip quality supplied to the UBC Nexterra gasifier

Gasifier combined heat and power:
1.7 MW power
10MMBtu/hr
12000 BDT/year





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CERC
Clean Energy Research Centre
BBRG
BIOMASS.UBC.CA

The overall research goal of this research program is to upgrade raw biomass to consistent high quality feedstock for biofuel and bioproducts.

High moisture (50%)
low bulk density (100 kg/m^3)

- **Low moisture <10%**
- **High bulk density >700 kg/m^3**
- **Meets biorefinery spec.**
- **Safe and economical handling and storage**

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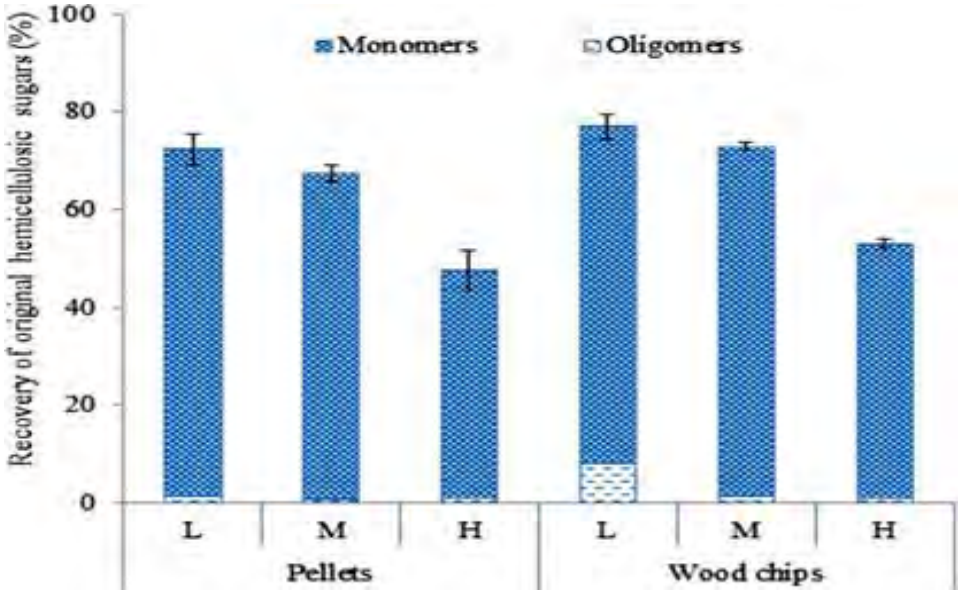
Recovery of sugars from steam treated pellets and wood chips

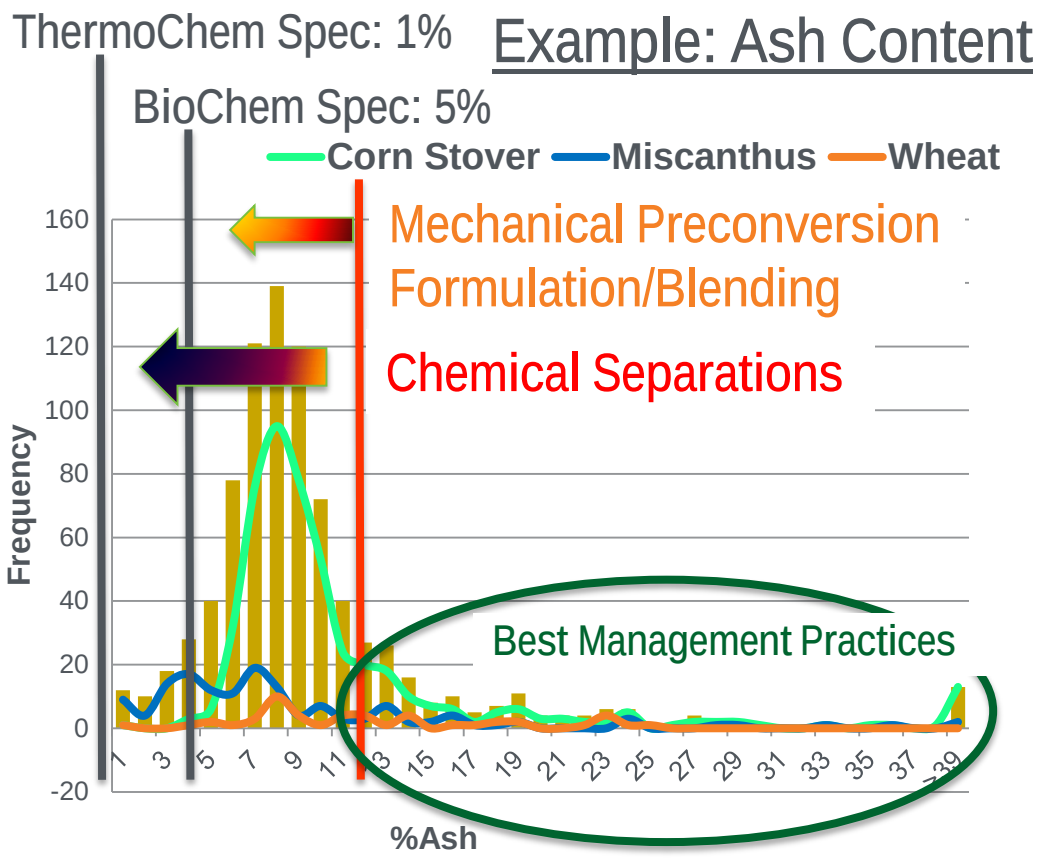
Figure 1- Appearance of raw material and pellets made in this study: (a) original Douglas fir woodchips, (b) SO_2-steam treated and dried woodchips, (c) pellets made from untreated particles, (d) Pellets made from SO_2-steam treated particles.



- Commercial wood pellets can be hydrolyzed to sugars (statistically insignificant compared to wood chips)
- Steam treatment using SO2 as a catalyst produced durable dense pellets, used less power input to make pellets than using steam only

The Feedstock Quality Challenge: Variability

- Challenge: Developing cost effective solutions to variability
- Solutions: a graded approach
  - Best Management Practices to reduce soil contamination
  - Preprocessing Technology R&D
    - Blending
      - Multiple sources of same feedstock
      - Different feedstocks
    - Mechanical Separations
      - Removal of non-structural ash (soil)
    - Chemical Separations
      - Removal of structural ash



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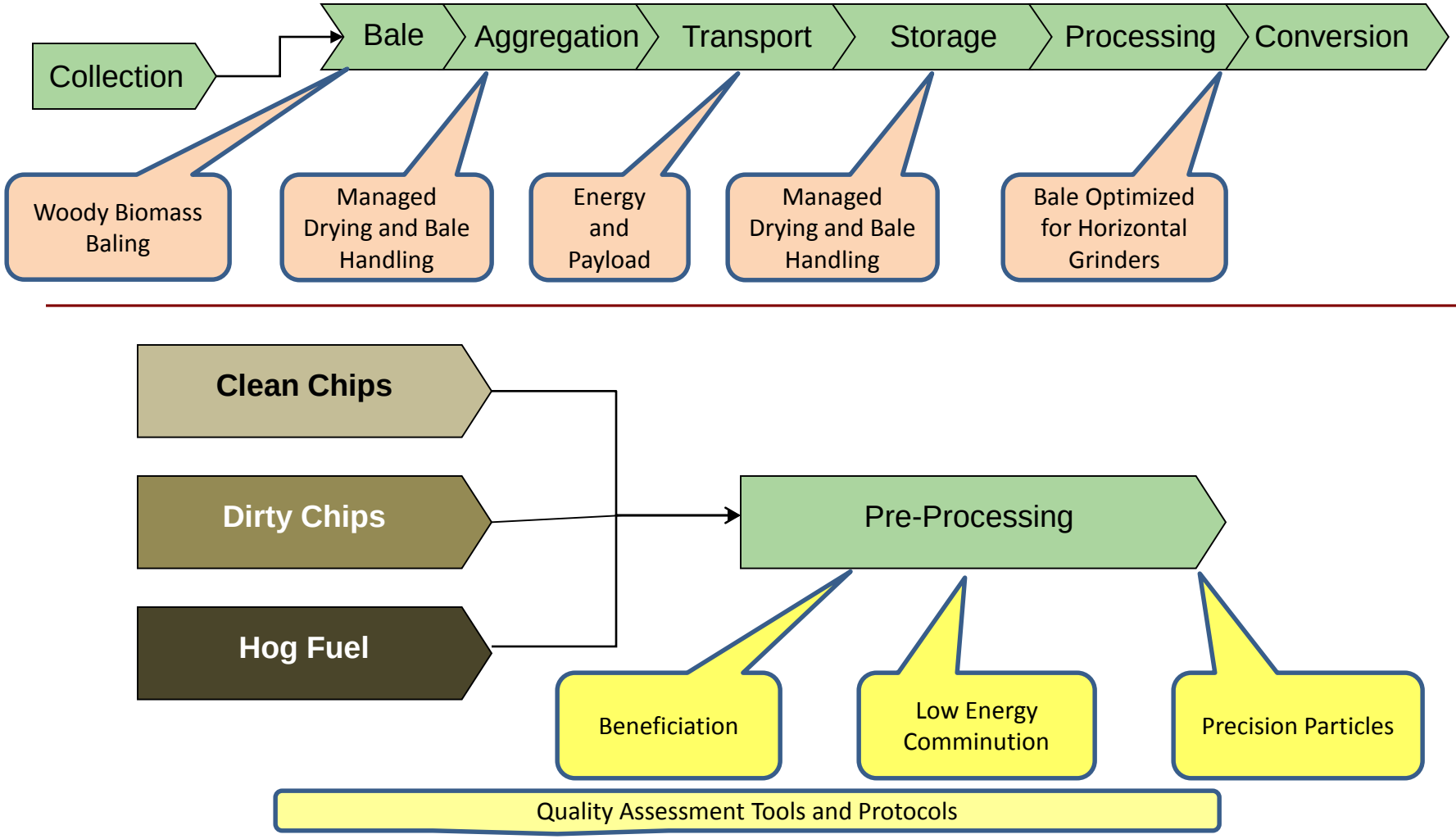
- Biomass collection and transport
  - Woody biomass baling – USDA SBIR
  - High density switchgrass, etc. baling – USDA SBIR
- Small diameter roundwood collection and transport – USDA SBIR
  - Ant-trail forwarding by hand crews
  - Wood-bunk unitization
- Beneficiation of chipped and shredded biomass – USDA SBIR
- Low energy comminution of biomass into optimal particles – USDA and DOE SBIRs
- Drying optimization to preserve quality and minimize energy – DOE and USDA SBIRs

Biomass Supply Chain



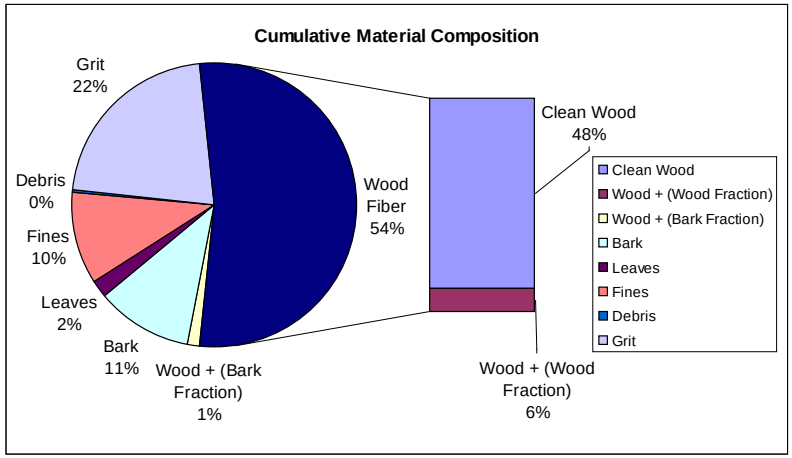
Precision Feedstocks™

- Separate the dirty end from the clean end of the cellulosic biomass industry

- Deliver feedstocks to users in the form and of the quality they need and are willing to pay for

Woody Biomass Beneficiation Project

- Objective – Develop technologies to reprocess hog fuel and urban chips into value-added fractions
  - Reduce dirt and grit to less than 1%
  - Reduce bark content to 1, 3, or 6 % Targets
  - Deliver clean streams of wood and bark



USDA SBIR Phase II Program began September 1, 2009 ($350,000)

Development is supported in-part by the USDA/NIFA Small Business Innovation Research program of the U.S. Department of Agriculture, grant numbers 2008-33610-18880 and 2009-33610-101114.

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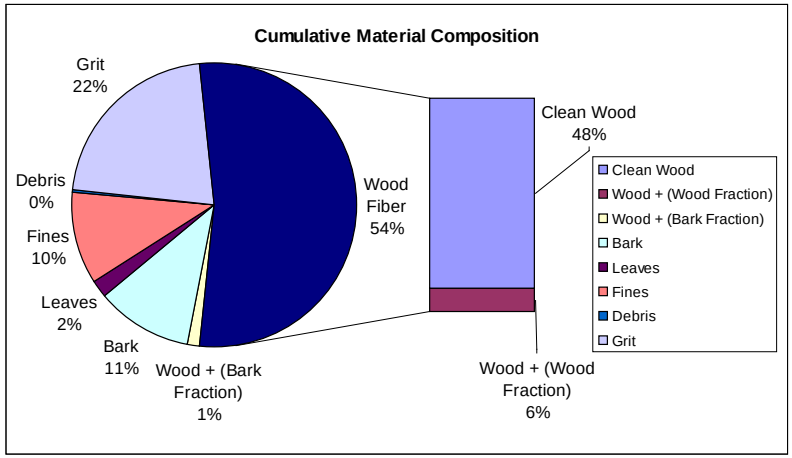

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SBIR Beneficiation Validation Test

Ground Land Clearing Debris - Seattle

Mass
100%
67%
60%
61%
57%

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

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

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

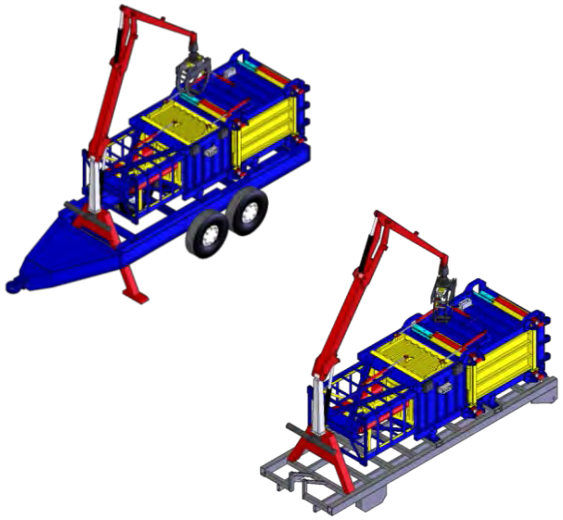
Wet Flail
77 % Wood
11 % Bark
13 % Other
1.1 % Ash

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

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.

Feedstocks, Industrial Machinery, Mobile Equipment



SBIR Contracts

SBIR - Small Business Innovation Research Program Competitive Awards to Forest Concepts	Agency Sponsor	Start Year	Amount ($)
Model-Based Dryer Control for Energy Conservation	USDA NIFA SBIR	June 2014	In Admin. Review
Low Energy Comminution of Herbaceous Crops	USDA NIFA SBIR	2013	$100,000
Methods to produce precision sub-millimeter wood particles	DOE/EERE Office of Biomass Technologies	2013	$150,000
Process Intensification through Improved Dryer Engineering Data and Design	DOE/EERE Office of Biomass Technologies	2012	$150,000
Low Energy Comminution of Woody Biomass	DOE/EERE Office of Biomass Technologies	2010	$1,100,000
Beneficiation of Chipped and Shredded Woody Biomass	USDA NIFA SBIR	2009	$430,000
Appropriate Technology Biomass Collection Systems for Energy and Value-Added Markets	USDA NIFA SBIR	2006	$375,882
Marketing and Logistics System for Roundwood Component Kits and Materials	USDA NIFA SBIR	2005	$375,359
Wood-Strand Erosion Control Material	USDA NIFA SBIR	2002	$375,824

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Thank You

www.forestconcepts.com

Development was supported in-part by the CSREES Small Business Innovation Research program of the U.S. Department of Agriculture, grants 2005-33610-15483 and 2006-33610-17595.

Development was supported by US Department of Energy SBIR contract DE-SC0003489.

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Critical Needs in the PNW

- Public agreements with refineries to accept advanced biofuels
  - Defined injection points
  - Agreed specifications for py-oil, biocrude and intermediates
- Permitted methods (and BMPs) for biofuel intermediates storage and transport
- Model air and water emissions “permits” for small scale primary conversion facilities of less than 100 tons per day (10,000 gal/day)
- Simple/no-cost permit modification for industrial biofuel users to convert from fuel oil to bio-oil/pyrolysis oil
- Simplified state permitting and approvals for the eight DOE vetted biofuel platforms that have completed LCA, etc.
- Pilot facilities to produce cellulosic biofuel for industrial and marine users

Our Innovations in Bioenergy…

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