Feedstocks for Scale-up and Build-out in the Cellulosic Biofuels and Bioproducts Industry

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Forest Concepts, LLC

Scale-up From 10 to 100 to 1,000 tons per day of biomass per facility
Build-out From 5 to 50 to 500 to 1,000 biomass consuming facilities
The math gets scary in a hurry!

An overview of the needs and benefits for the advanced feedstock supply system to mobilize biomass from an industry perspective
Core Business Questions

• How many facilities constitute critical mass?
• Site refinery or bioproducts facility near to biomass resource or next to customers?
• Biorefinery specialist vs vertical integration?
• Make from raw biomass or buy feedstocks?
• Proprietary vs commodity feedstocks?
• Single species vs feedstock agnostic?
• Low cost vs optimized feedstocks?
Scale – Number of Locations

- Pulp & Paper Mills ~ 120
- Ethanol biorefineries - 200+ in US (RFA)
- John Deere – nearly 5,000 dealers worldwide
- Grain Elevators & Warehouses ~ 8,800 (USDA)
Ideal Locations for First 20 Woody Biomass Biorefineries
Ideal Locations for First 20 +25 more Woody Biomass Biorefineries
Concept of Power Function Distribution

Facility Size (daily feedstock conversion capacity)

Number of facilities

More Smaller Facilities

Fewer Larger Facilities

Biochemical Pathway Firms

Thermochemical Pathway Firms
Distributed Production of Biofuels and Bioproducts

- Small Converters
- Gatherer
- Large Converter
- Integrated Biorefinery
- Small Biorefiners
- Gatherer
- Fuel Refiner / Blender
- Fuel Distribution
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A Different Paradigm
Industrial Biomass Feedstock Supply Industry

• Separate dirty and clean end of facilities
• Based on well defined commodity feedstocks
• Packaged appropriately for users
• Transported via conventional rail, barge, truck
Why the Interest?

<table>
<thead>
<tr>
<th>Biorefinery</th>
<th>Biomass Feedstock Producer</th>
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<tbody>
<tr>
<td>• Shift capital off-site (CAPEX)</td>
<td>• Increase revenue and gross margins</td>
</tr>
<tr>
<td>• Reduce biorefinery footprint (acres)</td>
<td>• Return screenings, leachates, etc. to the landscape as nutrients/amendments</td>
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<tr>
<td>• Reduce staffing</td>
<td>• Increase jobs in supplier communities</td>
</tr>
<tr>
<td>• Reduce truck traffic and receiving</td>
<td>• Profit by simplifying biorefinery operations and management</td>
</tr>
<tr>
<td>• Reduce fire risks from onsite storage</td>
<td></td>
</tr>
<tr>
<td>• Reduce waste &amp; soil disposal issues/cost</td>
<td></td>
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<tr>
<td>• Make variability someone else’s problem</td>
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</table>
Biorefinery Implications

• Particle Size & Shape
  – Comminution, steam explosion, digestion
  – Flowability, bridging, plugging

• Moisture Content – Storage and Drying
  – High moisture processes – “never-dried” feedstocks
  – Dry feedstock processes

• Environmental Ash Components
  – Abrasive grit, catalyst poisons, bad catalysts, waste disposal

• Biogenic Ash Components
  – Catalyze char and unwanted chemical species content
  – Catalyst poisons, acid consumers, waste disposal

• Upstream Chemical Preprocessing
  – AFEX™, torrefaction, hydrothermal, liquid intermediates, leaching, ...
More Questions than Answers!

• Where to make reactor ready feedstocks?
  – At producer, aggregator (woodyard), depot, …
• What are best processes and equipment?
  – Comminution, sorting, cleaning, washing…
• What are mass, energy, and LCA balances?
  – How are energy and LCA inventories allocated?
• What are economic benefits?
  – Rural economic development
  – Economies of scale of distributed processing
• What is the willingness to pay for reactor ready feedstocks?
  – How are benefits priced through the supply chain?
Low Cost vs Equitable Cost

Quality is like buying oats - if you want nice, clean oats, you must pay a fair price;

However,

if you're satisfied with oats that have already been through the horse - such oats can be had a little cheaper!!

Anonymous (oats were domesticated ~ 2000 BC)
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Potential Feedstock Products?

- Mechanically processed biomass
- Chemically enhanced & refined biomass
- Pellets, pucks, cubes, briquettes...
- Torrefied or thermally modified
- Partially digested – AFEX, SO$_2$, Steam treated...
- Hydrolysate, liquid mixed sugars, purified sugars
- Pyrolysis oil (bio-oil, bio-crude, Pyoil...)
- Syngas and purified/filtered gas
Forest Feedstock Situation

- Supply is abundant, BUT....
- No such thing as free wood – costs are real
- Competing uses set market value
- Environmental implications are still under study
- Public and interest groups have not bought in
What will be the Distribution of Biomass Converters by Size?
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 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.
This biomass stuff is harder than it seems!

• Mt. Shasta News – Oct. 10, 2007
  – “Biomass expectations unrealized, Opportunity Center project halted”
    • “The biomass electrical generation machine is being returned to its manufacturer after not living up to what may have been unrealistic expectations...”

• Nevada Appeal – March 2, 2008
  – “Prison biomass plant choked by supply costs”
    • “The plant has not run more than three days straight since it opened six months ago.”
    • “Wood continues to be an issue for us. We do not have an adequate and appropriate supply.”
“Bambi lives in the forest”
Toilet Paper vs Fuel
Attitude (Framing)

Scavenged Forest and Crop Residuals vs. Market-driven Products
Biofuel Supply Chain

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

- Fully Decoupled Supply Chain

Producer → Aggregator → Value-Added Processor → Distributed Pretreatment → Biorefinery → Fuel Refiner

Producer: Weyerhaeuser, Green Diamond, Greenwood, Sierra Pacific, NIPF Lands, State Forests
Aggregator: Price BioStock, Pacific Ag
Value-Added Processor: American Wood Fibers, Forest Concepts
Distributed Pretreatment: PureVision, Renmatix, Sweetwater, Renewable Oil, Cool Planet
Biorefinery: Virent, DuPont, Cargill, GEVO
Fuel Refiner: Chevron, Valero, Shell, BP
“A lot of companies spent all their money trying to build a single facility — to just get one running.” But that was the easy part. The hard part comes after the plant is built: It’s figuring out what to do when farmers don’t want to buy the equipment to bale up their cornstalks, or when a pile of biomass bursts into flames, or when that biomass comes in caked with mud, or when a central pump jams, or soil microorganisms wipe out your specially engineered fermentation bacteria.

— Chris Somerville, director of the Energy Biosciences Institute at the University of California, Berkeley
## Reactor-ready

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Reactor A</th>
<th>Reactor B</th>
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<tbody>
<tr>
<td>Right particle size</td>
<td>Pass 4mm, No-Pass 1mm</td>
<td>Pass 25mm</td>
</tr>
<tr>
<td>Right particle shape</td>
<td>Aspect ratio: 0.8 – 2.5</td>
<td>Aspect ratio: 0.5 - 20.0</td>
</tr>
<tr>
<td>Right moisture content</td>
<td>10 – 12 % wb</td>
<td>40 – 70 % wb</td>
</tr>
<tr>
<td>Acceptable anatomical content</td>
<td>&lt; 1% bark</td>
<td>N/A</td>
</tr>
<tr>
<td>Acceptable mineral and chemical content</td>
<td>Dilute acid washed</td>
<td>N/A</td>
</tr>
<tr>
<td>Total ash content</td>
<td>0.2%</td>
<td>12%</td>
</tr>
<tr>
<td>Upstream chemical preprocessing</td>
<td>N/A</td>
<td>AFEX – Ammonia treated</td>
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</tbody>
</table>
Supply Chain Pre-Processing Ops

• **Beneficiation** – cleaning and separation
  – Environmental ash – soil, silt, dust, salt
  – Contaminants – sand, rock, metal, plastic
  – Anatomical Fractionation – wood, bark, leaves
  – Washing – leaching catalysts and catalyst poisons

• **Comminution** – Size reduction
  – Size and shape creation

• **Moisture Control**
  – Drying, blending wet with dry, or preserving high moisture

• **Homogenization**
  – Blending across sources, species, ...

Adapted from INL Uniform Format Feedstocks program
Forest Concepts Technologies through the Supply Chain

Related Forest Concepts’ technologies

- Baling Biomass
- Crumbles® Particles
- Advanced Drying
- Managed Drying / Handling
- Beneficiation