SUPPLY CHAIN ANALYSIS

NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.
NARA GOALS

NARA’S GOALS ARE TO:

1. **Sustainable Biojet**: Develop a framework for a sustainable biojet fuel industry in the PNW that uses residual woody biomass as feedstock

2. **Value-added Polymer and Carbon Products from Lignin**: Create valuable co-products made from lignin, an industrial byproduct of the woody biomass-to-biojet process

3. **Rural Economic Development**: Sustain and enhance rural economic development

4. **Regional Supply Chain Coalitions**: Facilitate and promote supply chain coalitions within the NARA region for wood-to-biofuel supply chain analysis

5. **Bioenergy Literacy**: Improve bioenergy literacy to develop a future workforce and enhance stakeholder engagement, participation, and understanding
IDX Supply Chain Analysis

- WOODY BIOMASS
- KRAFT PROCESS
- PULP
- LIQUID DEPOT
- LIGNIN RECOVERY
- LIGNIN MARKET
- SUGAR MARKET

IDX | OP

Fall 2015

NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.
Woody Biomass

Woody biomass

Liquid Depot

Sugar Market

Lignin Recovery

Lignin Market

Kraft Process

Pulp

Casey Torres
Tyler Kerschener
Woody Biomass

What is Biomass

- Organic material that is available on a renewable basis

- Forest residuals include limbs, tree tops, stumps, and other debris from logging or thinning operations

- Residuals are typically put in slash piles and burned

Washington State DNR. Biomass as a renewable energy source. 03/23/11.

US Forest Service. Team helps businesses see benefits of using woody biomass. 07/06/11.
WOODY BIOMASS
RATIONALE FOR USE

• Forest residuals an underutilized renewable resource

• A step closer to energy independence

• Planes are not easily electrified, future market demand a safe bet

WSU News. Alaska Airlines plans biofuel test flight in WSU partnership. 06/03/15.
Holistic Vanity. Plane flying home. 12/17/09.
Woody Biomass

STUDY AREA

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Woody Biomass
Port Townsend Paper Corp. Volumes

10 Mile Radius: 6,000 BDT
30 Mile Radius: 55,000 BDT
50 Mile Radius: 112,000 BDT

BDT - Bone Dry Ton

Maps by Tyler Kerschner using NARA TPO Forest Density Data

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Woody Biomass

NIPPON PAPER INDUSTRIES VOLUMES

10 MILE RADIUS  11,000 BDT

30 MILE RADIUS  62,000 BDT

50 MILE RADIUS  224,000 BDT

Scale 1 in = 25 miles
### Woody Biomass Cost Data

#### 10 Mile Radius

<table>
<thead>
<tr>
<th>Volume</th>
<th>Cost/BDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>150CY Truck</td>
<td>$32.25</td>
</tr>
<tr>
<td>120CY Truck</td>
<td>$34.25</td>
</tr>
<tr>
<td>100CY Truck</td>
<td>$36.00</td>
</tr>
</tbody>
</table>

#### 30 Mile Radius

<table>
<thead>
<tr>
<th>Volume</th>
<th>Cost/BDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>150CY Truck</td>
<td>$40.50</td>
</tr>
<tr>
<td>120CY Truck</td>
<td>$45.25</td>
</tr>
<tr>
<td>100CY Truck</td>
<td>$49.25</td>
</tr>
</tbody>
</table>

#### 50 Mile Radius

<table>
<thead>
<tr>
<th>Volume</th>
<th>Cost/BDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>150CY Truck</td>
<td>$48.75</td>
</tr>
<tr>
<td>120CY Truck</td>
<td>$56.50</td>
</tr>
<tr>
<td>100CY Truck</td>
<td>$62.50</td>
</tr>
</tbody>
</table>

Data found using USFS Transportation Costing Model

Image from University Of Washington. Woody Biomass. 04/20/10.

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NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.
**LIQUID DEPOT**

**MILD-BISULFITE PROTOCOL**

- Has a general water to feedstock ratio of 4:1
- Optimal temperature at 145 degrees Celsius
- Optimal pressure at 315 kPa
- Cook time ranging from 180-240 minutes

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LIQUID DEPOT
BLOWING/SCRUBBING

- Temperature and pressure of the Pre-Treatment Liquor is reduced
- Steam created in the phase change can be recycled as a heat source in other areas of the facility

WASHING

- Separates spent sulfite liquor from clean substrate
- changes pH to levels suitable for enzymes
LIQUID DEPOT
ENZYMATIC HYDROLYSIS

- Converts Lignocellulose into glucose using enzymes
- Produces two streams, sugar slurry and residual solids
- Conducted in relatively mild conditions

Nara Supply Chain, https://nararenewables.org/docs/one-pager/supplychain.pdf
LIQUID DEPOT
ENZYMATIC HYDROLYSIS

- Lime is added to clean substrate to adjust pH
- Three types of cellulase enzymes are added to clean substrate
- Temperature is raised to approximately 120° F
- Process takes 24 to 72 hours
Liquid Depot

Conclusion

- Sugar Slurry
- Unfermented/Destroyed Sugars
- Insoluble Lignin
- Spent Sulfite Liquor (SSL)

2015 IDX, Liquid Depot TEA Report, Spring 2015

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**Sugar Slurry Market**

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Taylor Arndt
Victor Schlonga
WHAT IS IN OUR SUGAR SLURRY?

- Cellulose
  - Glucose
- Hemicellulose
  - Glucose
  - Xylose
  - Galctose
  - Mannose
  - Arabinose

WHAT IS IN COMMON SUGAR SOURCES?

- Sugarcane: Sucrose
- Sugar beats: Sucrose
- Honey: Glucose and Fructose
- High-fructose Corn Syrup: Glucose and Fructose

WHY DOES IT MATTER?
Sugar Slurry Market
Sugar market overview

Sugar Slurry

10,000 bdt/yr glucose

Isobutanol

15 million gallons/yr isobutanol

Isobutanol market

Market options available for in-house and out-of-house fermentation

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Sugar Slurry Market
Sugar Market Potential

BDO (1,4 Butanediol):
- Used in many products
- BDO Market worth $8.96 Billion by 2019

Livestock feed:
- Wood molasses similar to sugar slurry

Isobutanol Producers:
- Gevo

**Sugar Slurry Market**

**IsoButanol Market Potential**

Chemical companies have invested in bio-based alternatives:

- **Dow**
- **BASF**
- **DuPont**

**Revenue Growth**

- 2006 to 2015: $77.9b → $89.3b
- 2015 to 2020: $89.3b → $106.0b

**Industry Companies**

- 2006 to 2015: 35 → 45
- 2015 to 2020: 45 → 50

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LIGNIN RECOVERY

Cody Wuenstney
Brent Siegfried
What is Lignin?

Lignin is a constituent of the cell walls of almost all dry land plant cell walls. It is the second most abundant natural polymer in the world, surpassed only by cellulose. Of the polymers found in plant cell walls, lignin is the only one that is not composed of carbohydrate (sugar) monomers.
**LIGNIN RECOVERY**

**THE TWO LIQUORS**

**SSL (Spent Sulfite Liqour)**
- Sulfite Pulp Plant
- High Sulfite Levels
- Water Soluble
- 42% Lignosulfonates
- High Sugar Levels

**Kraft Liquor**
- Kraft Pulp Process
- Varying Degrees of Quality
- Acidic
- 40% Lignin
- 15% Solids

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**Lignin Recovery**

**Methods**

**Sulfite Pulping (SSL)**
- Ultrafiltration

**Kraft Pulping (Kraft Liquor)**
- LignoForce
- LignoBoost
- SLRP
LIGNIN MARKET

WOODY BIOMASS

LIQUID DEPOT

SUGAR MARKET

LIGNIN RECOVERY

LIGNIN MARKET

KRAFT PROCESS

PULP

Joey Malloy
Tyler Thornton

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LIGNIN MARKET
VOLUME VS. VALUE

Exchange Rate: 1 Euro = $1.13

LIGNIN MARKET
VOLUME VS. VALUE

Exchange Rate: 1 Euro = $1.13

Exchange Rate: 1 Euro = $1.13

Exchange Rate: 1 Euro = $1.13

LIGNIN MARKET
LIGNIN SUPPLY OVERVIEW

Potential World production of Biomass is 200 billion tons
• 50 million tons of lignin produced every year

2% of lignin is converted into products
LIGNIN MARKET
AVAILABLE FORMS

High Grade Lignin
  Organosolv Lignin
    Soda
    Kraft Lignin
  Lignosulfonates
    Low Purity
      (Kraft Liquor)

Aromatic Compound
  Carbon Fibers
  Bioplastics
    Resins
    Activated Carbon
    Sealants
    Bio-oil
    Bio-gas
    Char
    Cheap Fuel

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LIGNIN MARKET
AVAILABLE FORMS

High Grade Lignin
  Organosolv Lignin
    Soda
    Kraft Lignin
  Lignosulfonates
    Low Purity
      (Kraft Liquor)

Aromatic Compound
  Carbon Fibers
  Bioplastics
  Resins
  Activated Carbon
  Sealants
  Bio-oil
  Bio-gas
  Char
  Cheap Fuel

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LIGNIN MARKET
INCENTIVE RUNDOWN

Green Alternative

Reduced Carbon Footprint

Still can uses as fuel

Diversify
**LIGNIN MARKET**

GLOBAL LIGNIN INVESTMENT

Stora Enso
- $36.3-million USD (Finland)

Borregaard
- $8.5-million USD
- with Sappi (South Africa)

CIMV
- $22.7-million USD (France)

Suzano
- $20-million USD (Brazil)
LIGNIN MARKET
NORTH AMERICAN LIGNIN INVESTMENT

Borregaard
• $110-million USD
• JV with Rayonier (Florida)

West Fraser
• $10-million CA, 2014 (Canada)
• $6.1-million CA, 2015 (Canada)

Domtar Corporation
• $36-million USD (Quebec)
• $73.5-million USD (North Carolina)
• (Including lignin-production facility)
LIGNIN MARKET
POTENTIAL NORTHWEST MARKETS

Lignin in Building Materials

• Plywood
• Particle Board
• Oriented Strand Board (OSB)
• Gypsum Board
LIGNIN MARKET
POTENTIAL OP MARKET LOCATIONS

Legend
- Fuel Pellets Presto Logs
- Particleboard
- Veneer Plywood
- Engineered Wood Products
- Rail Lines

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LIGNIN MARKET
POTENTIAL 4-STATE MARKET LOCATIONS

Legend
- Fuel Pellets Presto Logs
- Particleboard
- Veneer Plywood
- Engineered Wood Products
- Rail Lines

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LIGNIN MARKET
KEY MARKET TRENDS

Housing Market Progress

Plywood Import Trends

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**LIGNIN MARKET**

CONCLUSION

Exciting Future Growth

Diversify With Available Material

Global Investment
  - Government
  - Private

Opportunities to lead in the NW
IDX Supply Chain Analysis

1. Woody Biomass
2. Kraft Process
3. Pulp
4. Liquid Depot
5. Lignin Recovery
6. Lignin Market
7. Sugar Market

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