

# What Are We Going to Do with All This Lignin?

## Quantity, Quality & Markets

Presentation to Frontiers in BioRefining , St. Simons Island GA  
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# Topics

## ➤ **How much lignin can be – and is being – made?**

- From papermaking black liquor
- From enzymatic conversion of biomass
- From solvent-based processes

## ➤ **What is the quality of that lignin?**

- What is purity?
- What are the major impurities?

## ➤ **What are the near-term markets?**

- Partial replacement of phenol in PF resins
- Other applications



# Who is Liquid Lignin?

- Formed in 2010 to commercialize SLRP™, a new process to recover lignin from papermaking black liquor
- Currently a four-person company
  - Michael Lake, PhD ChE
  - John Blackburn, PhD ChE
  - Charles Scouten, PhD Chem
  - Devon Stevens, BSChE
- Small, flexible technology-development company focused on lignin processes and applications
- Seeking partners to accelerate commercialization



# Potential Lignin from Kraft Pulping

## Assumptions:

- Total worldwide kraft pulp production = 130 million tonne/yr
- Klason (recoverable) lignin = 60% of pulp production
- Total potential capacity  $\approx$  **78 million tonne/yr**

## Current Manufacturers (start-up year) tonne/yr

- |  |                  |
|--|------------------|
| 1. MWV in North Charleston SC (late 40s) | $\approx$ 40,000 |
| 2. Domtar in Plymouth NC (2013)          | $\approx$ 20,000 |

## Announced Start-Ups (year)

- |   |                  |
|---|------------------|
| 3. Stora Enso in Finland (2015)         | $\approx$ 50,000 |
| 4. West Fraser in Hinton Alberta (2015) | $\approx$ 10,000 |

**Only 0.2% of potential realized by end of 2015**



# Lignin Technologies for Kraft Pulping

1. MWV is proprietary and not available for licensing
2. LignoBoost™ developed by Swedish national lab; marketed by Valmet
3. LignoForce™ developed by Canadian national lab; marketed by Noram
4. SLRP™ developed by Liquid Lignin Company; seeking financing

## SLRP Advantages

1. CAPEX is lower
  - LignoBoost ≈US\$ 20 million for 20,000 Te/yr w/o dryer or scrubber
  - LignoForce ≈CA\$20 million for 10,000 Te/yr
  - SLRP ≈US\$10 million for 20,000 Te/yr
2. Emissions are lower (< 1.0 Kg/day TRS from 20,000 Te/yr facility)
3. OPEX is lower (30% lower CO<sub>2</sub> usage due to acid-gas recycle)
4. Equipment is smaller (footprint is 12m wide x 18m deep x 12m high)



# Potential Lignin from Cellulosic Ethanol

## Assumptions:

- Cellulosic ethanol = 120 billion liter/yr (twice US RFS)
- All ethanol is from enzymatic conversions with recoverable lignin
- Ethanol yield = 400 liter/tonne biomass
- Lignin = 20% of dry biomass
- Recoverable lignin = **60 million tons/yr**

## Start-Ups:

	<u>Location</u>	<u>Feedstock</u>	<u>million liter/y</u>
1. Abengoa	Hugoton KS	corn stover	95
2. POET/DSM	Emmetsburg IA	corn stover	95
3. DuPont	Nevada IA	corn stover	95
4. Quad County	Galva IA	DDG	7
5. Shengquan	Jinan China	corn cobs	16
6. GranBio	Alagos Brazil	bagasse	80



**Only 0.3% of potential; all lignin likely burned for fuel value**

# Potential Lignin from Solvent Pulping

**No commercial operations; several in development**

1. **CIMV's Biolignin™**
2. **Renmatix's Plantrose™**
  - Uses near-critical water as a solvent on hardwood
  - Pilot plant in King of Prussia PA
  - Funded by UPM, BASF
3. **Tennera's evolUTIA™ (UT Knoxville)**
4. **THF-CELF (UC Riverside)**
5. **GVL (UW Madison)**
6. **Lignol Innovations' Alcell™ process**
  - Uses ethanol and co-solvent at elevated temperature
  - Demonstration facility operated in Newcastle Canada in 90s
  - Company in receivership as of August 2014



# “Quality” of Lignin

## From Papermaking Black Liquor

- Purity > **98%**
- Impurities are inorganic ash, primarily  $\text{Na}_2\text{SO}_4$
- MW set by pulping conditions and functionality set by trees used as feedstock
- Organically-bound sulfur gives lignin characteristic “paper mill odor”

## From Enzymatic Cellulose Conversions

- Purity nominally **90-95%** exiting fermenter
- Impurities are unconverted cellulose and hemicellulose, proteins, plant oils, enzymes, inorganic ash, other; all solids leaving fermenter are included in this crude lignin
- Requires purification process before use other than fuel

## From Solvent Processes

- Capable of very high purities, >**99%**
- MW determined by pre-treatment processes
- Functionality determined by plants used as feedstock





# How Much Lignin is Needed?

## Market Reports

- Frost and Sullivan (2012) projects \$130 Bn/yr market
- Lux Research (2014) projects \$242 Bn/yr market

## Assumptions

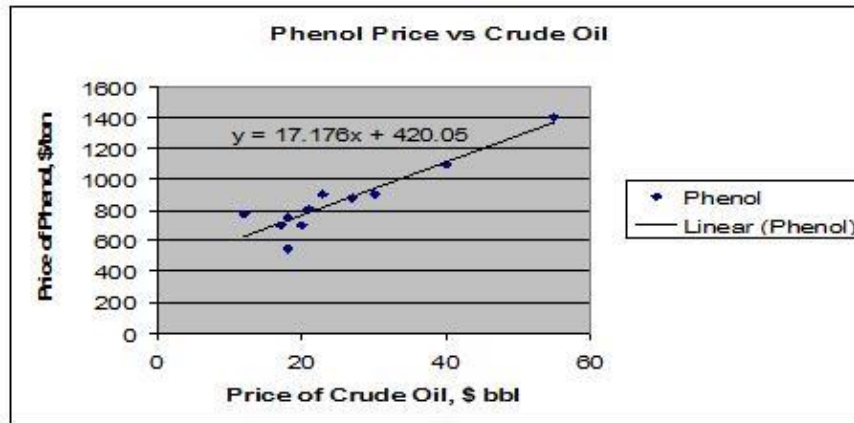
- Total lignin market is US\$186 Bn/yr (average of above projections)
- Value of lignin = \$1000/tonne
- Lignin needed to satisfy long-term market = **186 million tonne/yr**

**More lignin is needed to satisfy the projected demand!**



# Market for Polymeric Lignin: PF Resins

- Initial lignin sales will be to partially replace phenol in PF resins
  - Lignin can replace up to 40% of the phenol; 10% is easy
  - Lignin's cost of manufacture from papermaking is <\$500 per tonne
  - Graph below plots contract phenol price (y-axis) vs crude oil price (x-axis)
  - With crude oil at \$80/bbl; phenol price is projected to be ≈\$2000/ tonne



- PF market > 10 million tonne/yr



# Future Markets for Polymeric Lignin

## ➤ **Functional Fillers Polymeric Composites**

- cycleWood uses lignin at 25-30% loading to make compostable garbage bags

## ➤ **Asphalt Emulsifiers**

- Lignin-polyamine condensates can make 70% asphalt emulsions

## ➤ **Polyurethanes**

- Lignin can partially replace polyols to make stiff PU foams for insulating panels

## ➤ **Wastewater Treatment Polymers**

- Lignin can be cross-linked to form effective flocculants

## ➤ **Carbon Fiber**

- WHEN successful, this will be a HUGE market for lignin



**The old worn-out adage of**

**“You can make anything from lignin,  
but you can’t make money”**

**is now used only by people  
who don’t know any better!**



# Thank You!

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