Opening Remarks

• Agenda

• WWII, DOD, wood pulp mill waste, ethanol.

• Today, 70 years latter, wood waste, butanol/ jet fuel

• Personal irony
Today’s Outline

• Definitions of NARA Wood Bio Refinery Co Products
• Bio Refinery Feedstock and Co Products Raw Material
• Potential Co Products
• Nara Co Product Teams and Research Projects
• Selected Revenue Generating Co Products for TEA
• What have we learned
NARA Process Flow Overview

Techno-Economic Analysis
What are NARA Wood Bio Refinery Co Products

IPK (Jet Fuel) = 13%

Everything Else:
- Fermented Calcium Lignosulfonate
- FRS – Activated Carbon
- CO₂ Fines as boiler fuel
- Miscellaneous Other
  - Boiler Ash
  - Anaerobic NG
  - Light Ends
  - Protein sludge

Feedstock = 100%

- Hexan: 56%
- Lignin: 31%
- Pentan: 6%
- Extractives: 7%
• Co Product, A specific product with positive revenue, targeted to a specific consumer with agreed quality specifications
NARA Co Products by Research Team

- Manuel Garcia-Perez (WSU) and Weyerhaeuser Team
  - Activated Carbon

- Simo Sarkanen (University of Minnesota)
  - Lignin derived plastic (Polystyrene)

- Weyerhaeuser Co Products Team
  - Characterization of MBS SSL and FRS
  - Concrete Dispersant

- Jinwen Zhang/Mike Wolcott (WSU)
  - Partially Depolymerized Lignin (PDL), Epoxy-Asphalt

- Xaio Zhang (Bio-Products, Science and Engineering Lab, WSU)
  - Carboxylic acids
  - Milled wood lignin characteristics
NARA Co-Products Research Portfolio

- **Activated Carbon:**
  - D. Fish, I. Dallmeyer, C. Fox, M. Garcia-Perez, and W. Suliman; (Weyco & WSU)
  - Utilizes total FRS mass, carbonizes, CO2 Activated (22% total yield)
  - AC captures Hg from coal power plant stack emissions, Hg tests performed
  - Pretreatment is important in porosity formation

- **Plastic:**
  - Simo Sarkanen, University of Minnesota
  - Twice Ultra filtered Lignosulfonate for intermediate MW
  - Lignosulfonate-based polymeric materials ..... Polystyrene and Polyethylene

- **Epoxy Asphalt:**
  - Jinwen Zhang, Junna Xin, and Mike Wolcott
  - Catalytically partially depolymerized Lignin (PDL) reacted with Epichlorohydrin yields a PDL-epoxy
  - PDL-epoxy appears to be comparable to bisphenol A type epoxy in asphalt modification
  - Compared to original asphalt, PDL-epoxy asphalt shows better viscoelastic performance

- **Concrete Dispersant**
  - D. Fish, C. Fox (Weyerhaeuser)
  - SSL; Preliminary Concrete Testing

- **Dicarboxylic Acid (DCA) and Milled Wood**
  - Xiao Zhang, WSU and BSEL, Richland, WA (joined team in August, 2015)
  - DCA via CuFeS$_2$ in the presence of H$_2$O$_2$ (e.g., muconic, maleic, succinic acids)
  - Micronized wood lignin characterized
Co Products Selected for TEA

- Fermented Ca-LS
  - Concrete test positive
  - Market Size and Risk
  - Price estimated at $200 per dry ton

- Activated Carbon
  - Gas Absorption
  - Hg capture in coal power plant flue gas
  - Market size and risk
  - Price estimated at $1500 per dry ton
“Lignin” Supply History, Caution Required

World Production of Paper (MM Tonnes)

- Lignin to Fuel
- Lignin to Waste
- Lignin to Chemicals
- Recycled Paper

1867 Bisulfite Patent
1877 First Bisulfite Mill
1890 First Kraft Mill
1930 Recovery Boiler

Thomas Spink Inc.
Moving Forward Messages

- Wood Bio Refinery residuals are many molecules not just “Lignin”
- Pretreatment makes a difference in Activated Carbon properties
- High margin Co Products are required for total bio refinery success
- “Lignin” is too broad a term. More specificity is required.
- A successful commercial “lignin” product faces a potential huge raw material supply
- Separation technology is essential
Thank You

- Thank you for your time today

- Questions