



Wood Bio Refinery Co-Products A NARA Report

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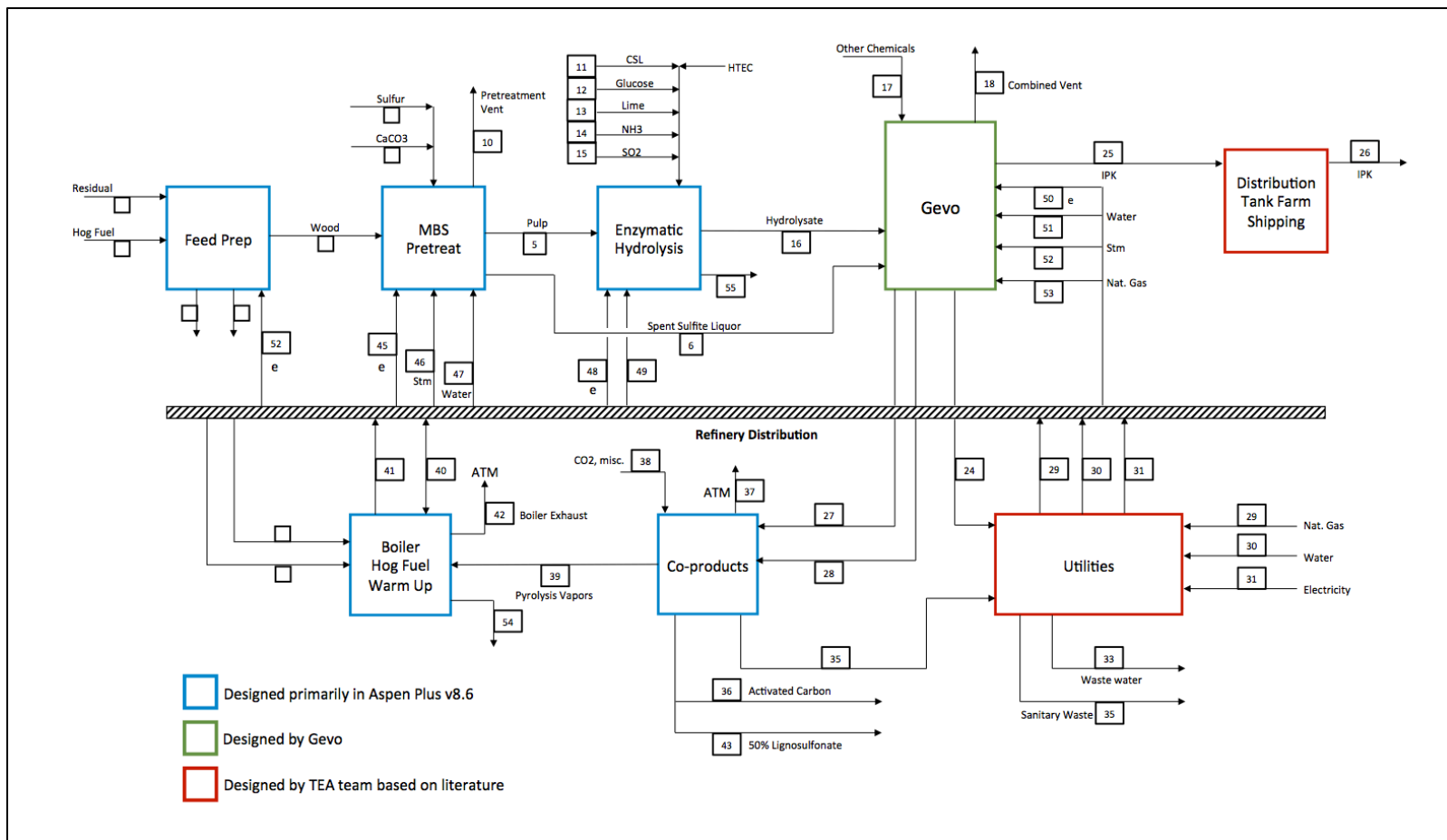
NARA Summary Conference, Washington DC

Embassy Suites, Crystal City

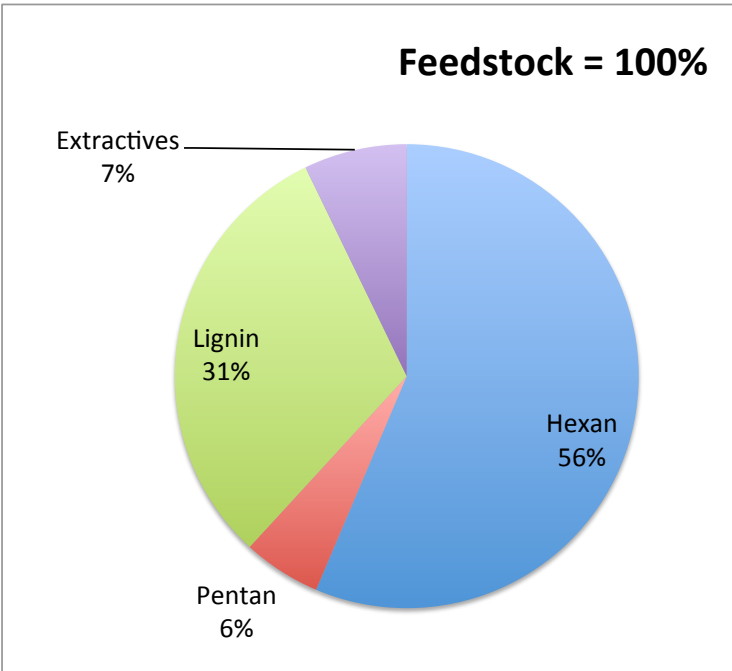
- Agenda
- WWII, DOD, wood pulp mill waste, ethanol.
- Today, 70 years latter, wood waste, butanol/ jet fuel
- Personal irony

- 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



What are NARA Wood Bio Refinery Co Products



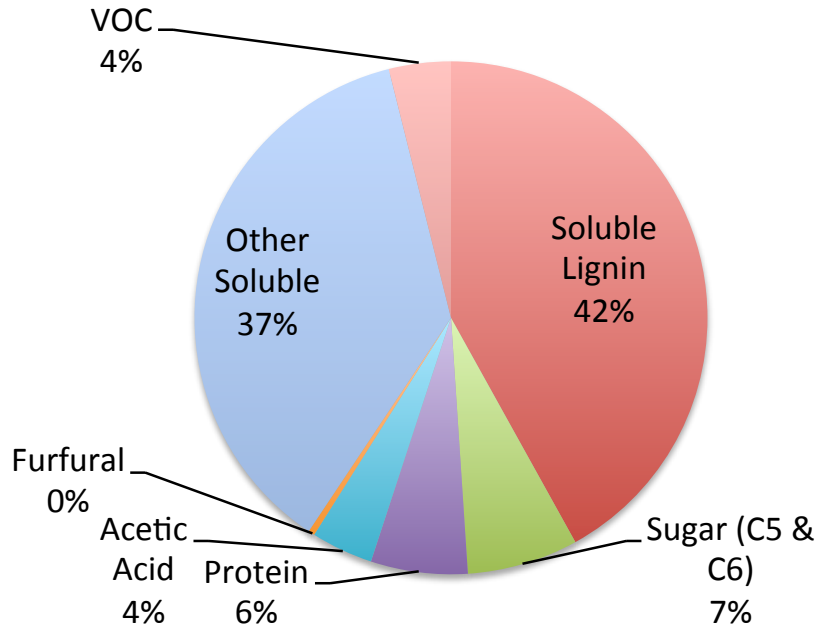
+ Chemicals
& Processing

IPK (Jet Fuel) = 13%

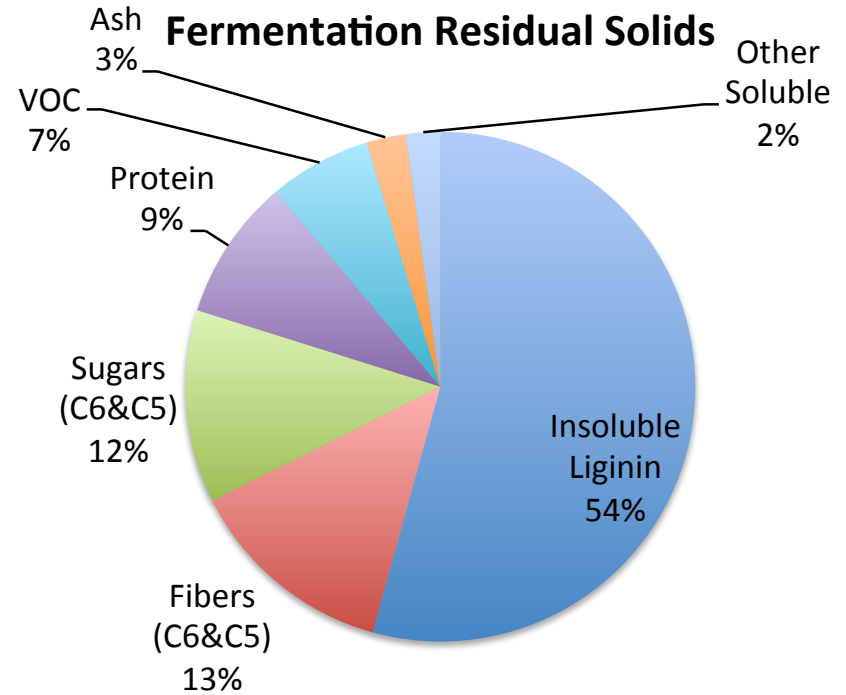
Everything Else:

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

Pretreatment Spent Sulfite Liquor



Fermentation Residual Solids



- Co Product, A specific product with positive revenue, targeted to a specific consumer with agreed quality specifications

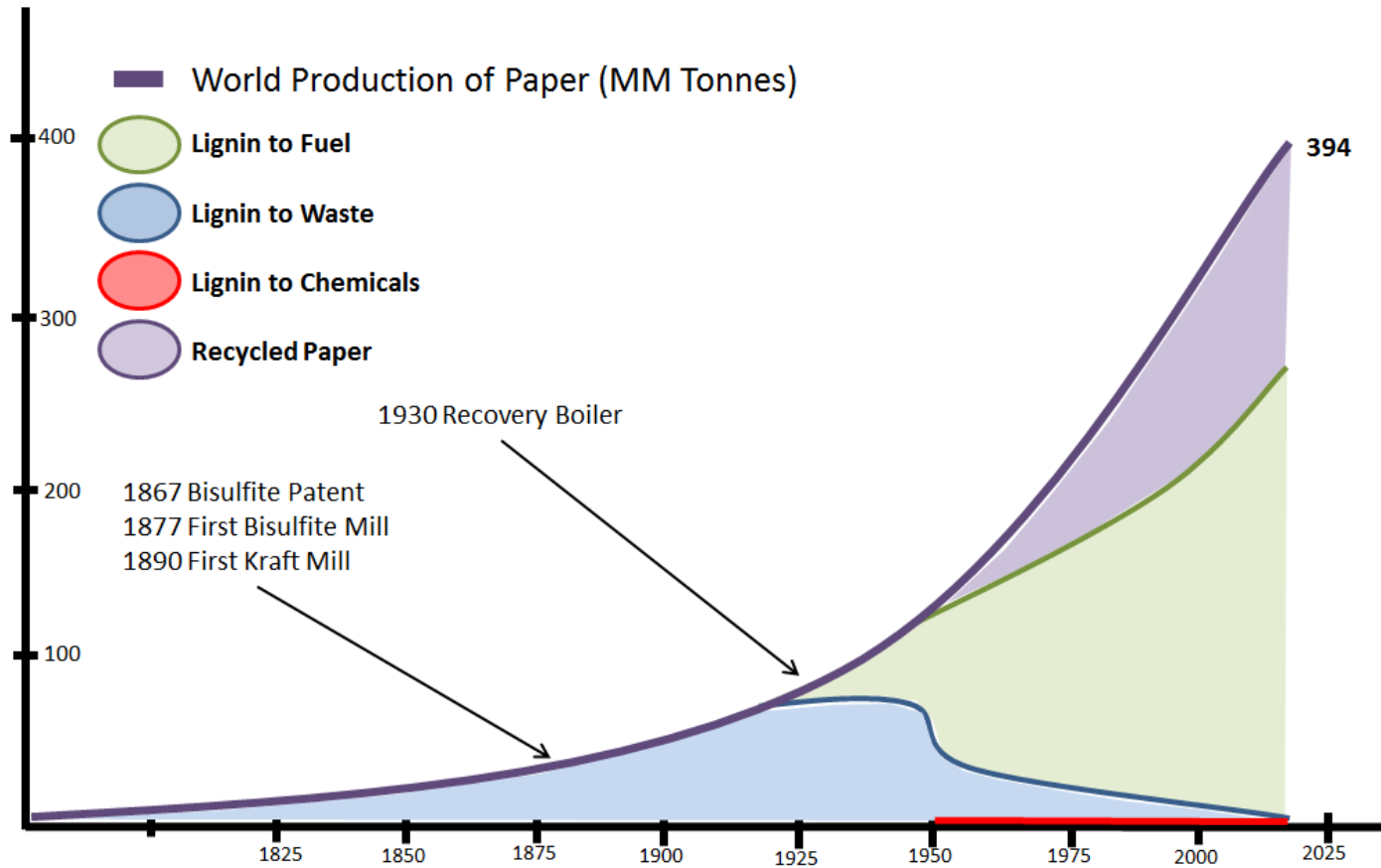
- Manuel Garcia-Perez (WSU) and Weyerhaeuser Team
 - Activated Carbon
- Simo Sarkanen (University of Minnesota)
 - Lignin derived plastic (Polystyrene)
- Weyerhaeuser Co Products Team
 - Characterization of MBS SSL and FRS
 - Concrete Dispersant
- Jinwen Zhang/Mike Wolcott (WSU)
 - Partially Depolymerized Lignin (PDL), Epoxy-Asphalt
- Xaio Zhang (Bio-Products, Science and Engineering Lab, WSU)
 - Carboxylic acids
 - Milled wood lignin characteristics

- 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 CuFeS₂ in the presence of H₂O₂ (e.g., muconic, maleic, succinic acids)
 - Micronized wood lignin characterized

- 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



Thomas Spink Inc.

- 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 for your time today
- Questions