Lignol ENERGY

Cellulosic Ethanol

TAPPI

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High Yield, High Value Biorefining for Cellulosic Ethanol

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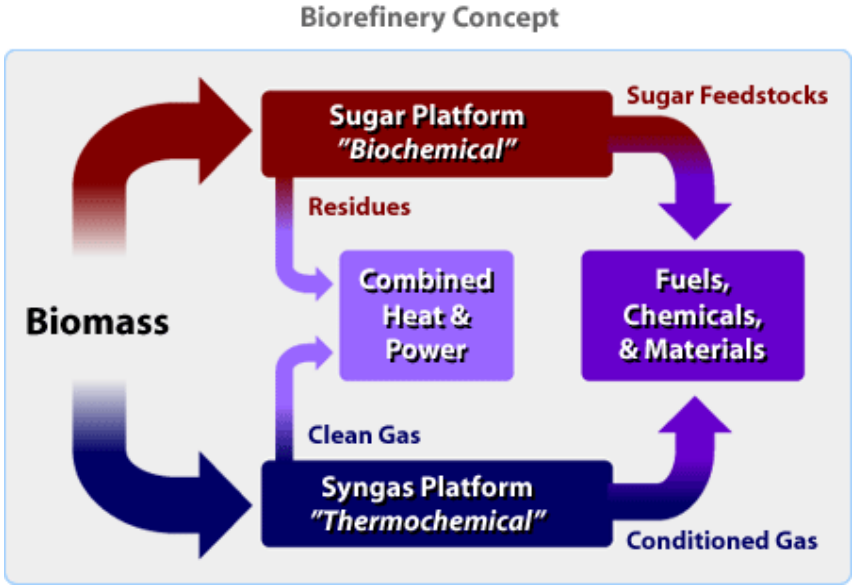
Biorefineries for Lignocellulosic Biomass

- NREL Definition of Biorefinery

"A facility that integrates biomass conversion processes and equipment to produce fuel, power and chemicals from biomass".[1]



1. National Renewable Energy Laboratory website, www.nrel.gov/biomass/biorefinery

Pulp mills are biorefineries

- Chemical pulp mills are simple biorefineries
  - Most produce chemicals (pulp) and steam and power (from liquor burning in a recovery boiler)
  - Some produce additional chemicals: tall oil, turpentine, kraft lignin, lignosulfonates, even ethanol from hemicellulose sugars (sulfite)
  - Primary function is to produce pulp and paper not transportation fuels

The “New” Biorefinery

- New biorefinery technologies focus on production of ethanol and other sugar platform chemicals from cellulose and hemicellulose fractions of lignocellulosic material
- New biorefineries tap more deeply into chemical values in woody biomass:
  - Three major polymers that are physically integrated and chemically bonded
    - Cellulose (~35% to 50%)
    - Hemicellulose (~25% to 35%)
    - Lignin (~12% to 30%)
- Biorefineries require a pretreatment step to separate wood into components, followed by bioconversion steps to convert cellulose to sugars and sugars to ethanol

Biorefinery pretreatment options

- Pretreatment options
  - steam explosion, with or without acid pretreatment
  - mechanical disintegration
  - acid treatment
  - organosolv treatment
- Lignol's modified organosolv delignification removes the lignin from the fibre:
  - Lignin - High value byproduct vs. disposal as fuel
- This process originates from Repap/Alcell organosolv pulp process

The Lignol Biorefinery Process

- A solvent-based organosolv delignification stage, enzymatic saccharification of the cellulose, fermentation to produce fuel grade ethanol
- Recovery of a very pure form of lignin
  - Less than 0.5% sugar
  - Less than 0.1% ash
  - Approximately 3% moisture
  - Less than 0.3 ppm sulfur
  - Very low water solubility
  - Number Average Mol. Wt., approximately 850 daltons
- Recovery of furfural, extractives and other co-products

Lignol acquired technology developed by General Electric and Repap (Alcell)

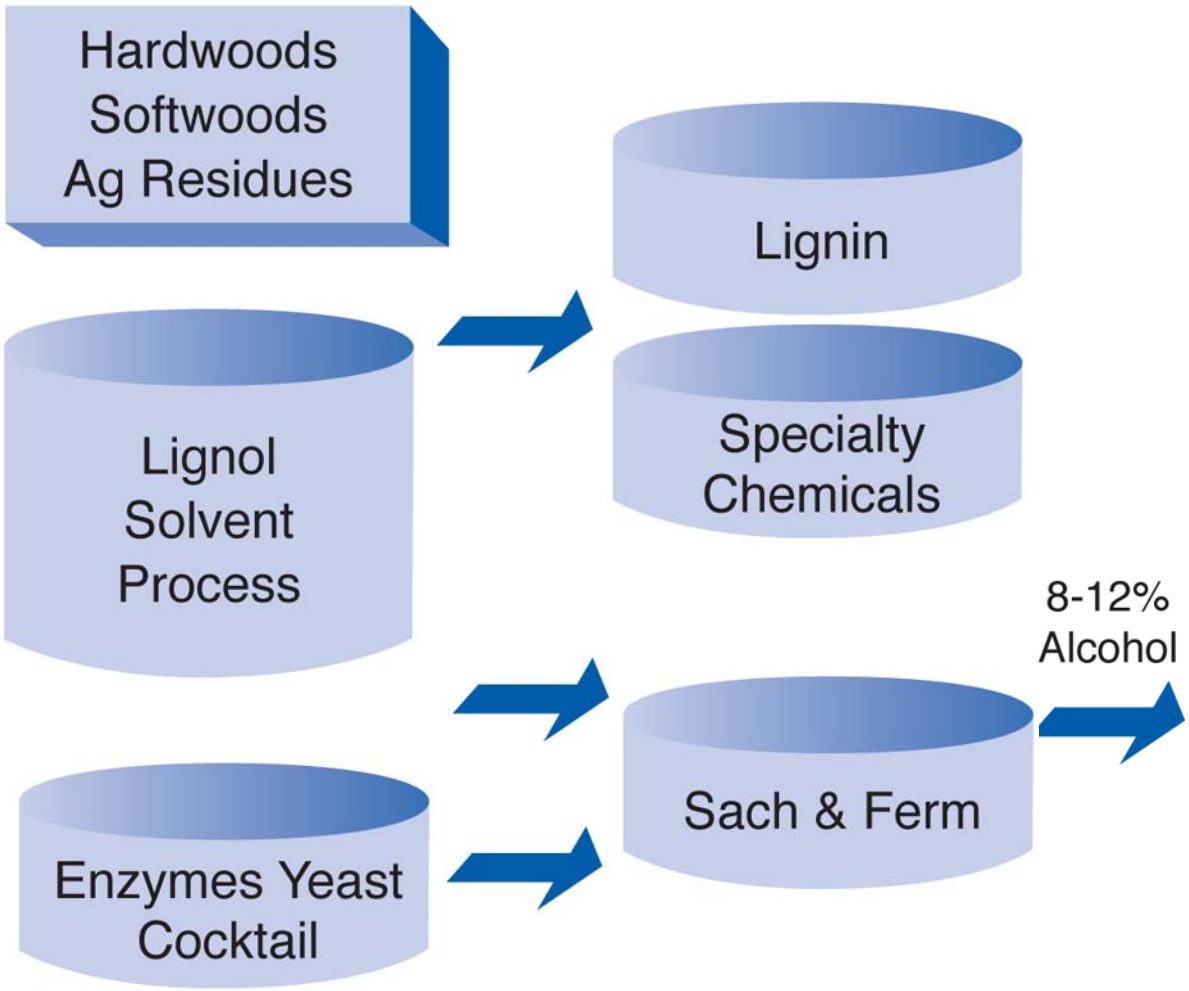
GE

- Wood to ethanol pilot plant

Alcell

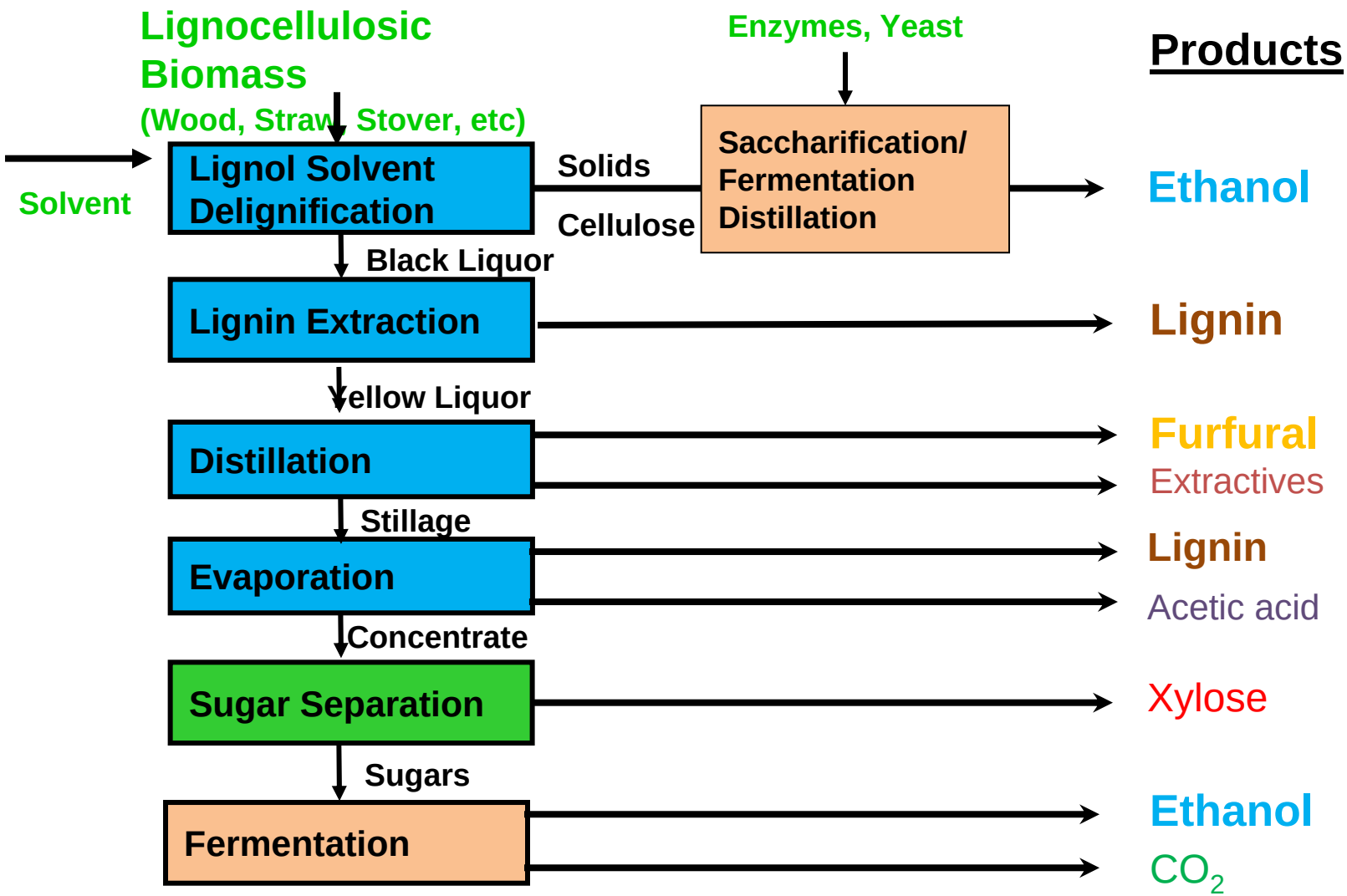
- Wood pulp production at industrial scale
- Markets for novel “High Purity Lignin” (HPL™) established

Optimized for Superior Economic Returns



Distillation to Ethanol

Lignol Biorefinery Platform



Some Commercial Applications for Lignol Lignin

Chemical value ~ 10x Fuel value

HPL™ – Some demonstrated applications

- PF resin and wood adhesive substitute
- Printed circuit board encapsulating resins
- Foundry resins and molding compounds
- Degradable plastic films, coatings
- Friction materials, green strength binders, organic particles
- Antioxidants in rubber, lubricants, feed additives
- Rubber tackifiers
- Renewable surfactants; concrete admixtures, air-entrainers, super-plasticizers
- Carbon fibre and activated carbon production
- Animal feed applications

Potential Feedstocks

- Hardwoods
- Softwoods
- Chips, residues, sawdust
- Annual fibres
- Agricultural residues
- Mixed or campaigned feeds

Process Performance

- Yields of ethanol and lignin depend on feedstock and operating and product targets
- Range of performance parameters:

  - Ethanol yield: 150-300 litres/tonne OD feed
  - Lignin yield : 130-200 kg/tonne

Economically Sustainable at Small Scale

- Efficient ethanol production
  - Lower enzyme requirements than other cellulose to ethanol technologies; very high yields from cellulose
  - Better pre-treatment leads to lower capital and operating costs
- Multiple co-product revenue streams
- Sited at forest industry facilities with infrastructure, utilities and feedstock supply

Potential Markets for Lignol Lignin

- Global markets for known applications - US$2 billion

  International Lignin Institute, *Eurolignin Network Project*

- Examples
  - PF and other resins 3.5 million tonnes/yr
  - Surfactants, concrete, etc. 2.5 million tonnes/yr

Conclusions

- Lignol biorefineries offer an opportunity for the forest products industries to increase profits and leverage their existing resource base and infrastructure
- The technology is compatible with existing operations, technology base and labor force
- Industrial markets for the renewable chemicals and transportation fuels produced are large and robust with significant growth potential
- Lignin revenues provide a major boost for biorefinery economics