

Bioproducts from Dissolving Pulp Manufacturing

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FPIInnovations: Largest National Integrated Forest Research Institute



Paprican Pointe Claire, QC

- **Paprican** (pulp & paper), **Forintek** (wood manufacturing), **FERIC** (logging) and **Canadian Fibre Centre**
- Member-based research program is supplemented by **contract research and consulting** for companies around the world
- Bioenergy and biorefinery research is funded by NRCan and largely conducted out of Paprican
- Paprican - 228 scientists and technicians, 15 FTEs on biorefinery research
- www.fpinnovations.ca

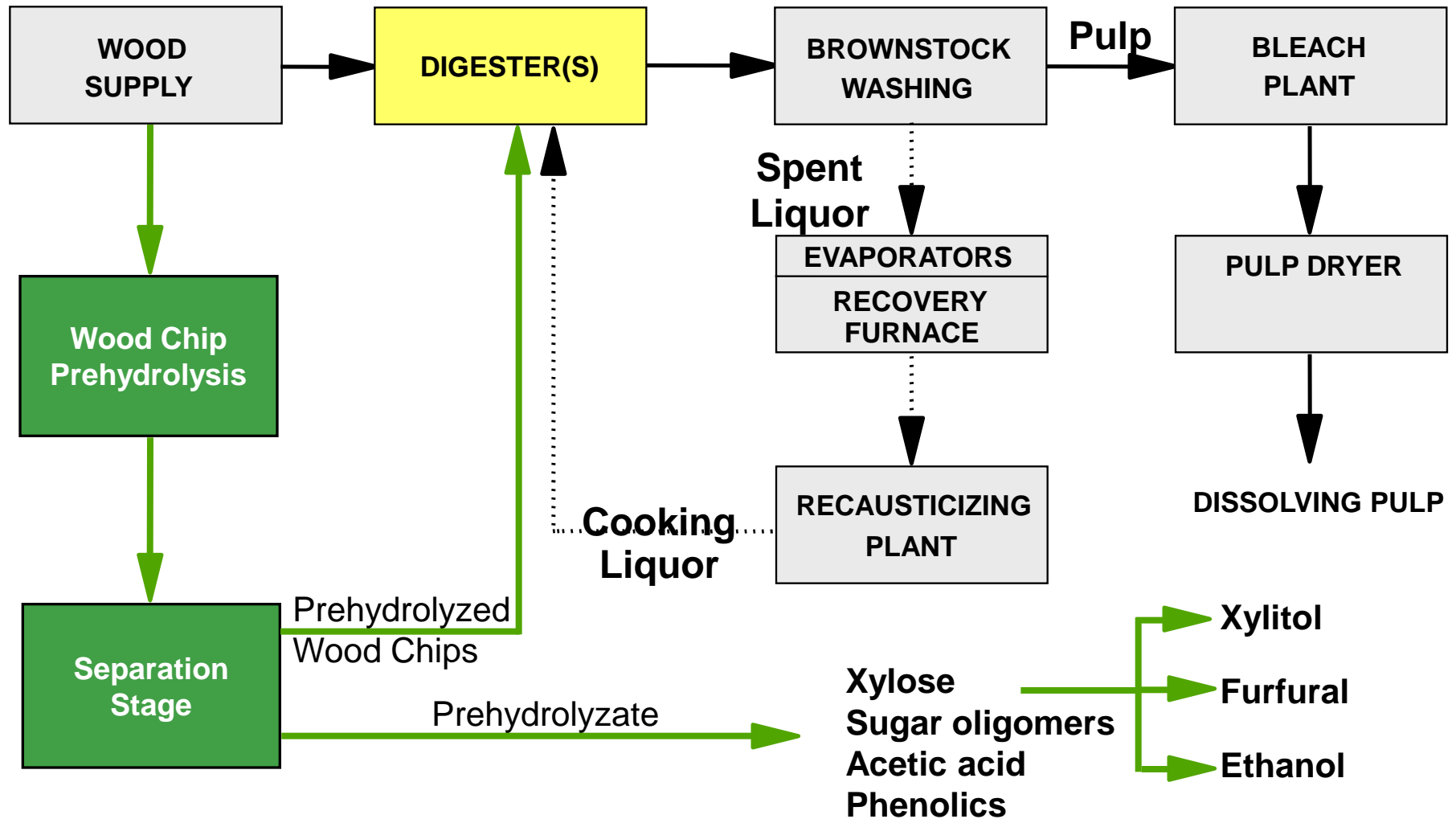


Paprican Vancouver, BC

Canadian Market Kraft Industry

- Ten out of 43 kraft mills have closed in the last four years
- Remaining mills need to diversify their product portfolio
- Dissolving pulp from pre-hydrolysis kraft process is established technology
- Opportunity to increase fibre value and provide a hemicellulose stream

Potential Chemical Products from Kraft Mill



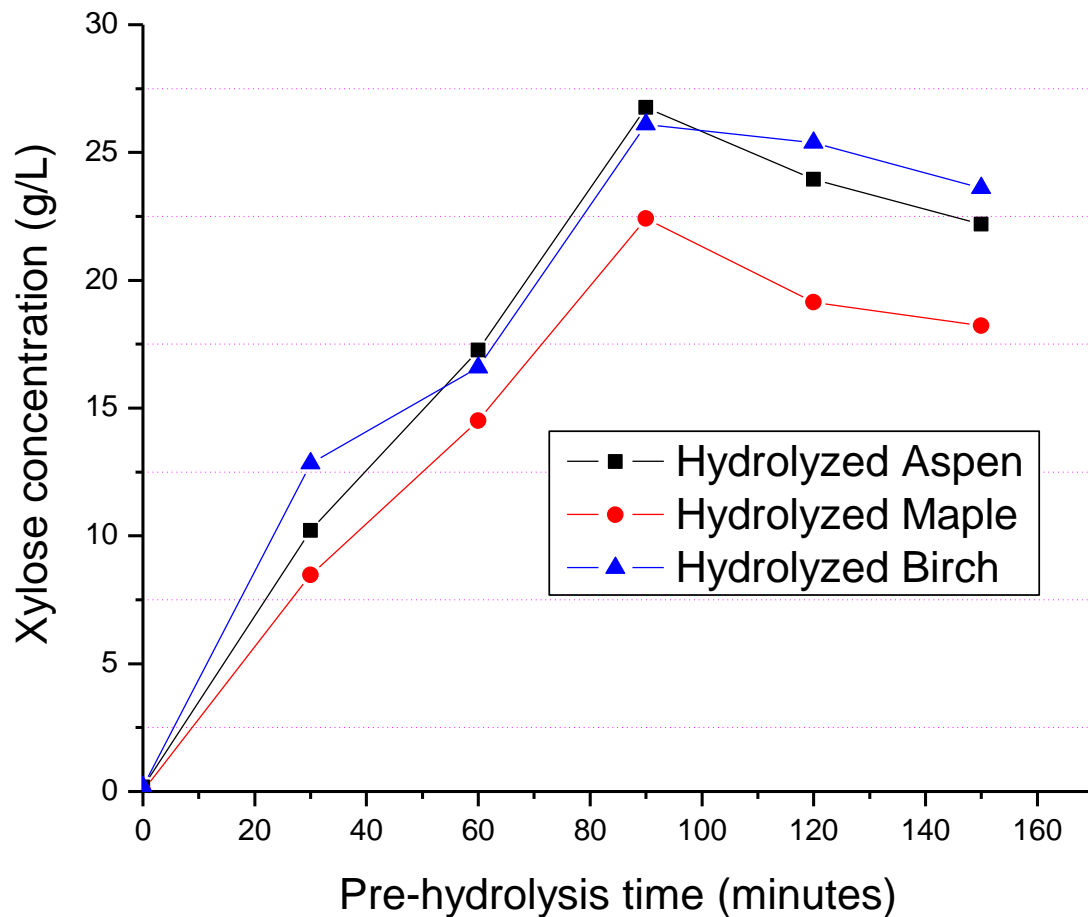
Hardwood Prehydrolysis Kraft

- What are the optimum prehydrolysis conditions?
 - Must produce pulp to meet customer specifications
 - Maximize byproduct stream yield and concentration
- What products are in the initial prehydrolyzate?
- Can they be used without further conversion or separation?
- What are the potential product markets?
- What technology can be used to produce marketable products?

Characterization of Kraft Prehydrolyzates

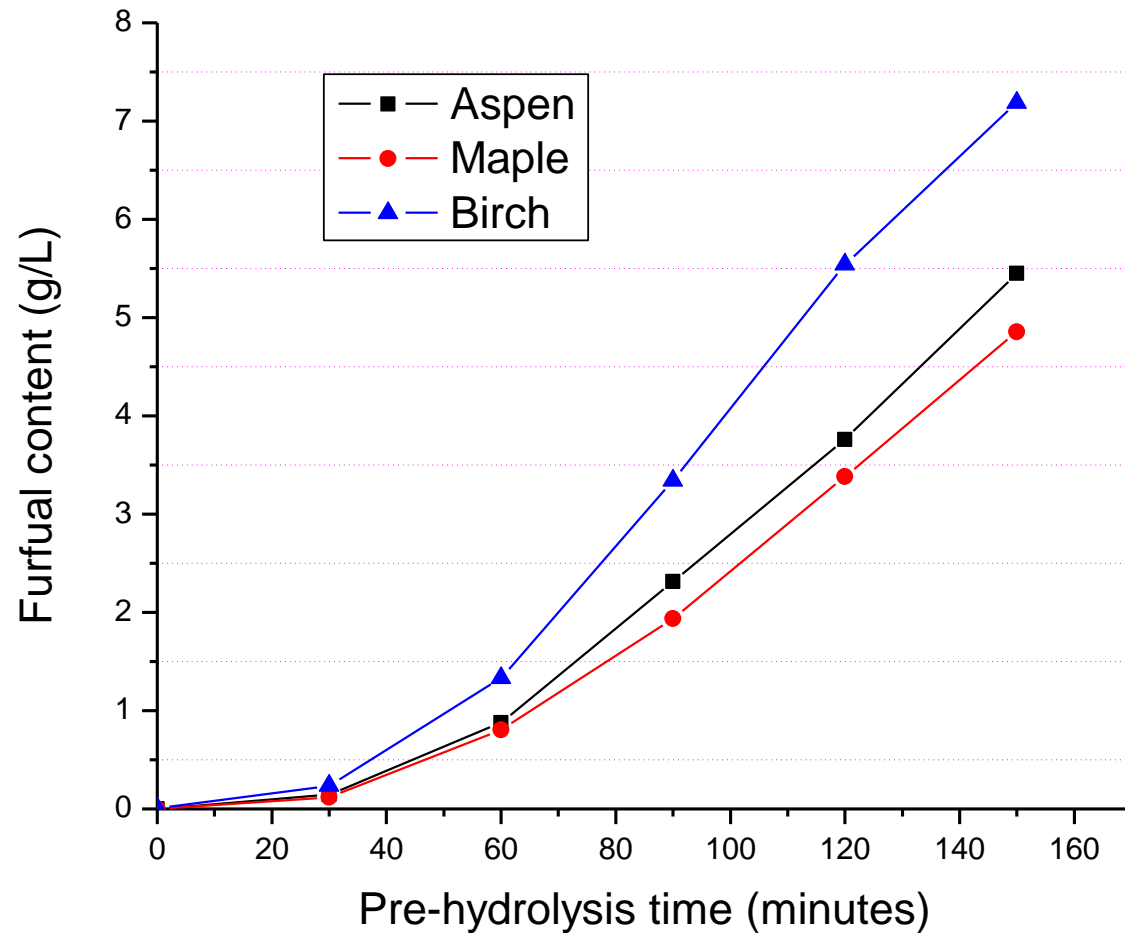
- Sugars:
 - Monosaccharides: arabinose, xylose, mannose galactose, glucose.
 - Oligosaccharides: galactoglucomannan, glucuronoxylan, etc.
- Other chemical compounds:
 - Acetic acid
 - Furfural, Hydroxymethylfurfural (HMF)
 - Phenolic compounds

Major Sugar from Hardwoods



More than 10% of wood can be recovered as xylose

Some Conversion of Xylose to Furfural



Options for the Prehydrolyzate

- The prehydrolyzate stream can be used as a feedstock to:
 - The mill recovery cycle for the production of steam and electricity, but this limits pulp production
 - A fermentation plant for the production of ethanol or methane
 - A chromatographic/ crystallization system for the purification of xylose and xylitol
 - A further acid treatment to produce furfural

Ethanol Price and Market Size

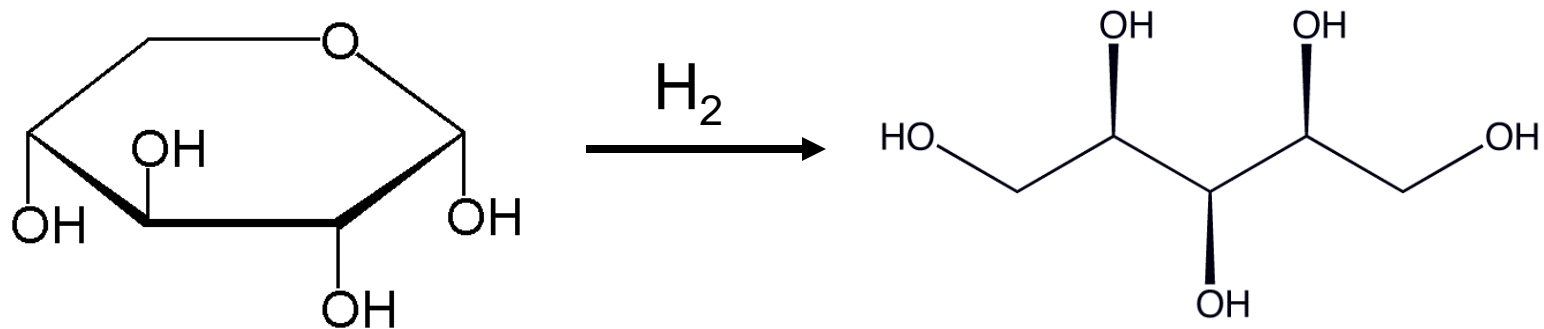
- Price currently dictated by price of corn and barrel of oil
- Market size: 64 billion L/y by 2022 (US target)
- Typical prehydrolysis kraft mill could produce about 25 million L/y
- Assumes that major sugar product (xylose) can be efficiently fermented

Pentose-Fermenting Yeasts

- Pentose-fermenting yeasts were discovered in 1981-1982 by Canadian Henry Schneider
- Problems still exist:
 - Glucose and mannose will be used preferentially over xylose and arabinose
 - Sensitive to various inhibitors found in lignocellulosic substrates
- Working with U Concordia/Guelph to improve strains:
 - *Saccharomyces cerevisiae*: classical mutagenesis and xylose isomerase expression.
 - *Pickea stipitis*: mutagenesis and genome shuffling

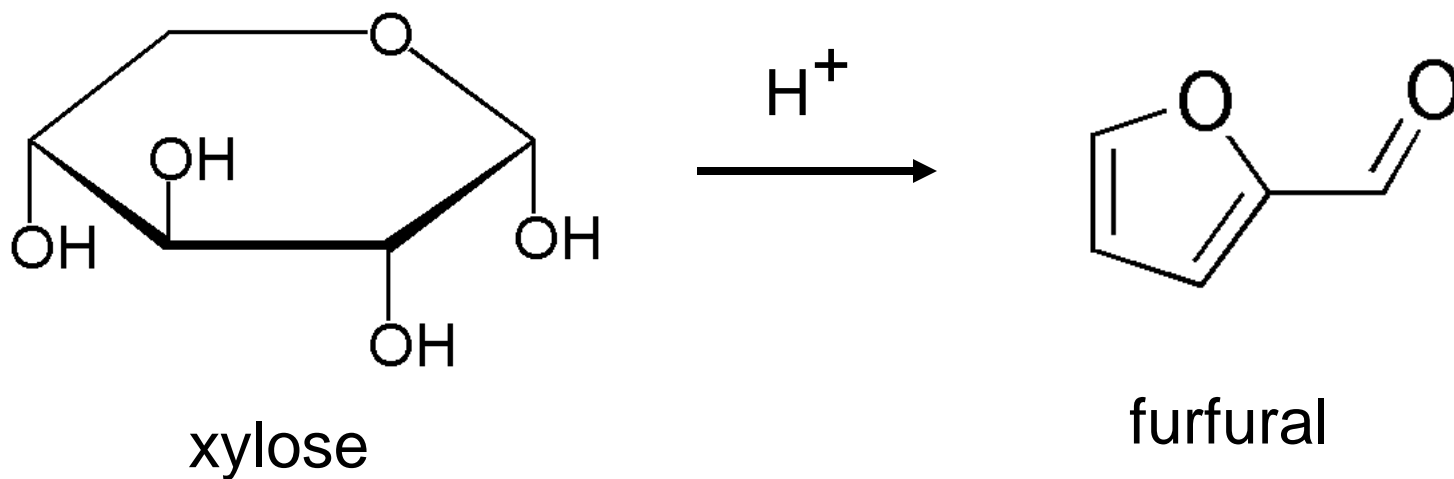
Xylitol - anticariogenic sweetener

- Largest producer is Danisco
- Current (2000) world market size for polyols is 1.4 million tonnes (US\$1.6 billion)
- Xylose is purified by chromatography and crystallization, then hydrogenated to xylitol



Furfural

Produced by acid dehydration of xylose



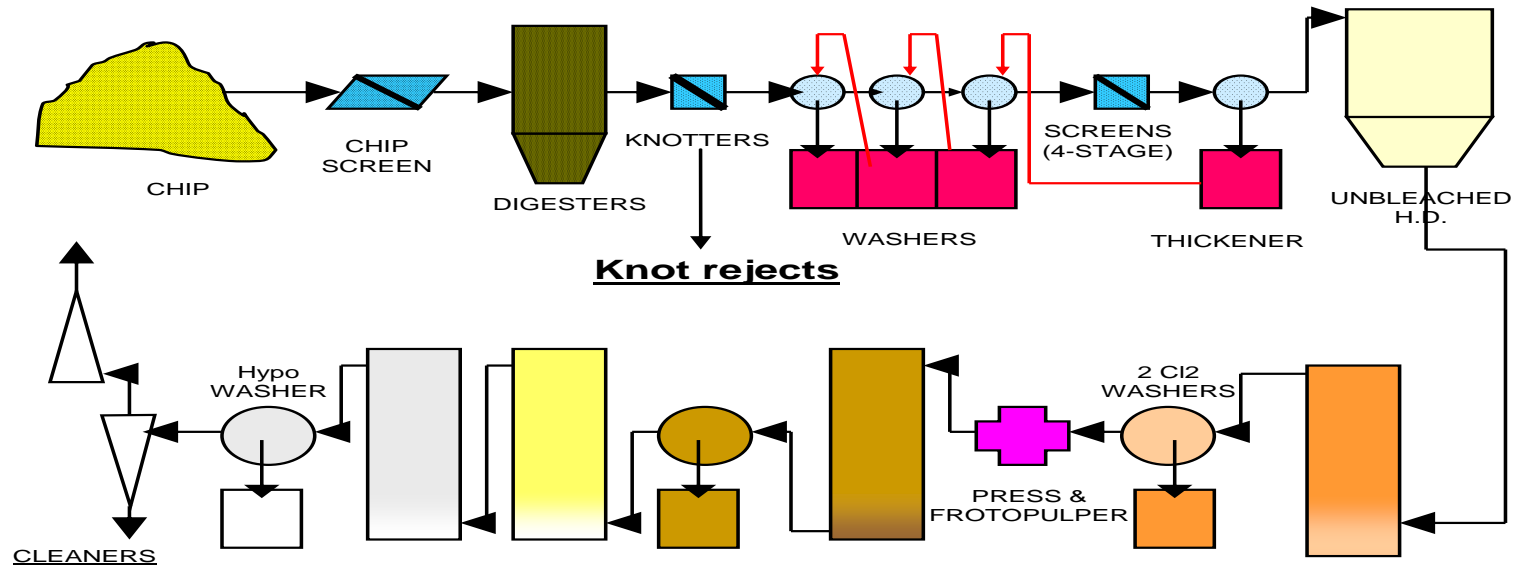
Market Size for Furfural

- Global production in 2001 was 225,000 tonnes
- Most furfural is now produced in China, where capacity is 150,000-200,000 tonnes/y
- Prices have fallen over the last 20 years from \$1740/tonne in 1990 to ~ \$1000/tonne today
- A 1000 tonne/d hardwood kraft pulp mill could produce about 90 tonnes/d of xylose
- If all the xylose is converted to furfural such a mill will have the potential of producing 27500 tonnes/y
- Several hardwood kraft mills exist in Canada and the North Eastern part of the US

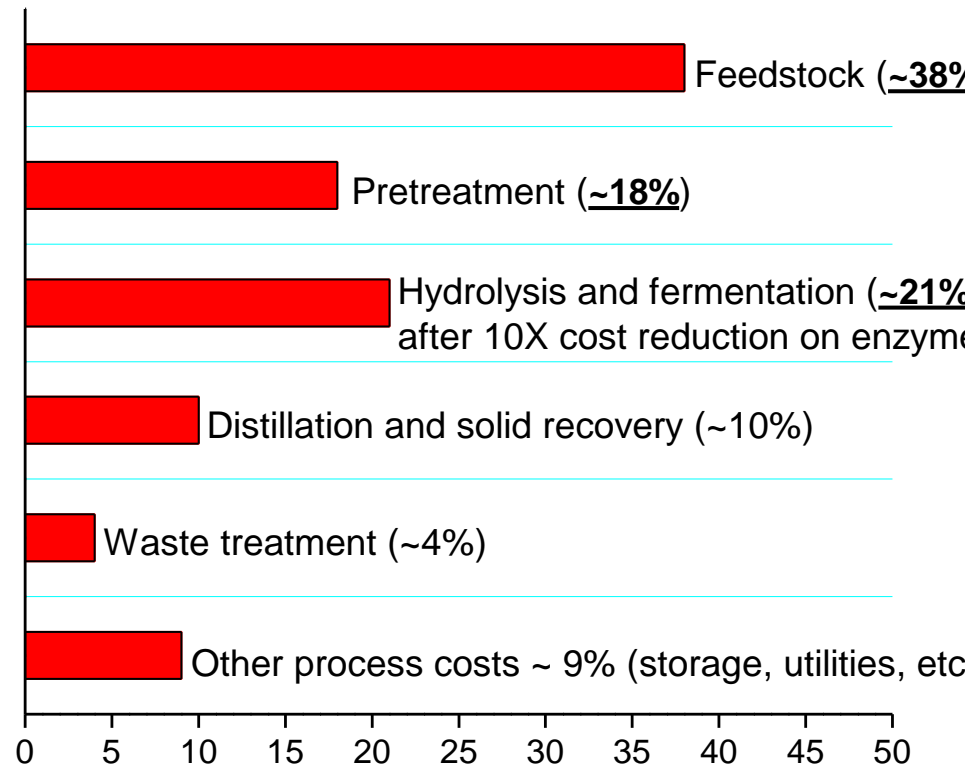
Resource Recovery

- Effective effluent treatment will still be needed for future biorefineries
- Existing effluents are a (dilute) source of acetic acid, methanol, fibres, biomass
- Can be recovered as
 - Methane
 - PHA plastics
 - Ethanol and other fermentation products

Sulfite Pulp Manufacturing



Relative Cost Components for Cellulosic Ethanol



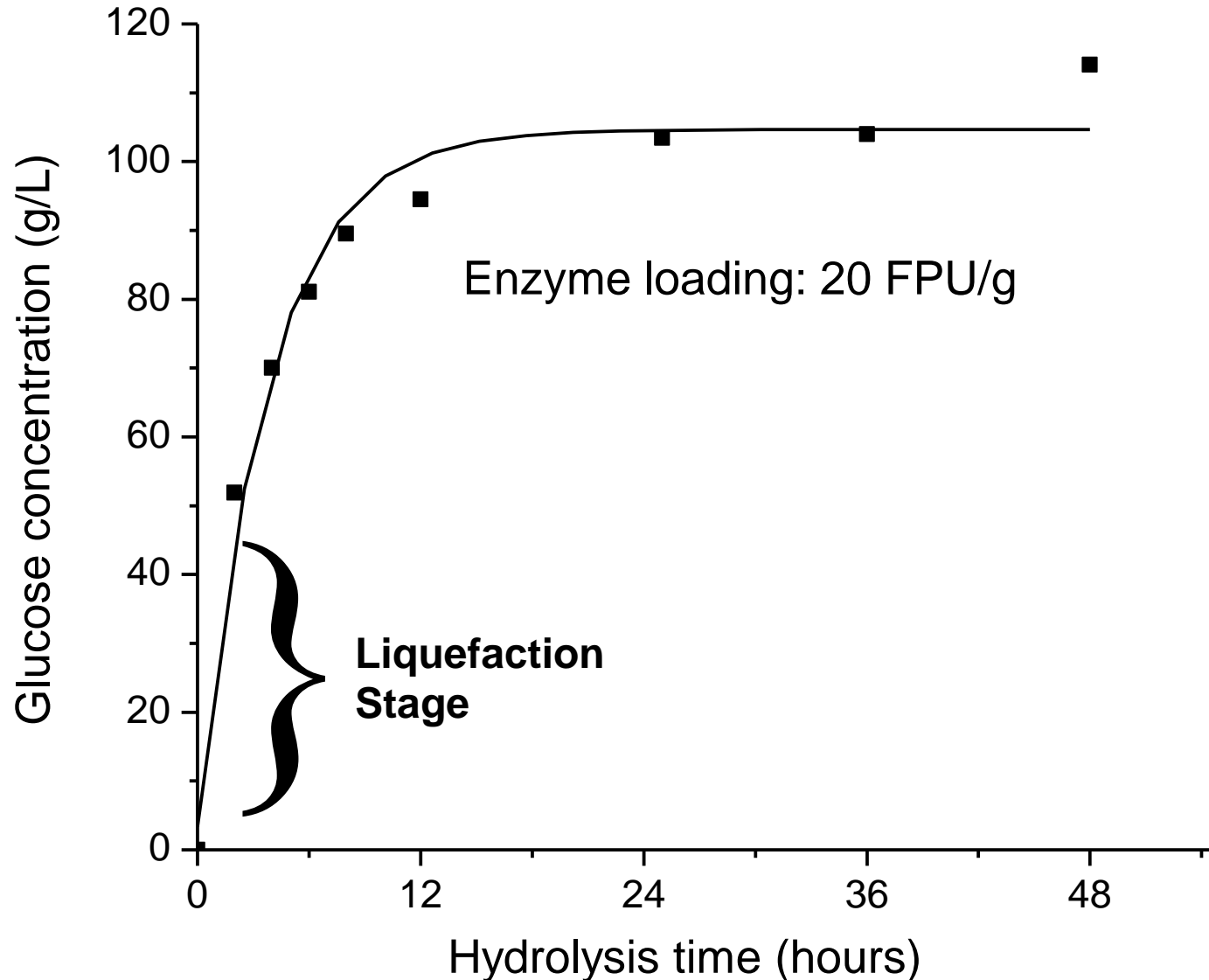
Percentage cost by area (%)

Adapted from NREL

Cellulosic Ethanol

- Enzyme hydrolysis costs
 - High consistency process in development
 - Higher sugar concentration in smaller vessels
 - Advances in enzyme recycle
- Applied to cellulosic residues from sulfite pulping
 - Lab and pilot trials
 - Patent applied for

High Consistency Hydrolysis of Cellulosic Residues



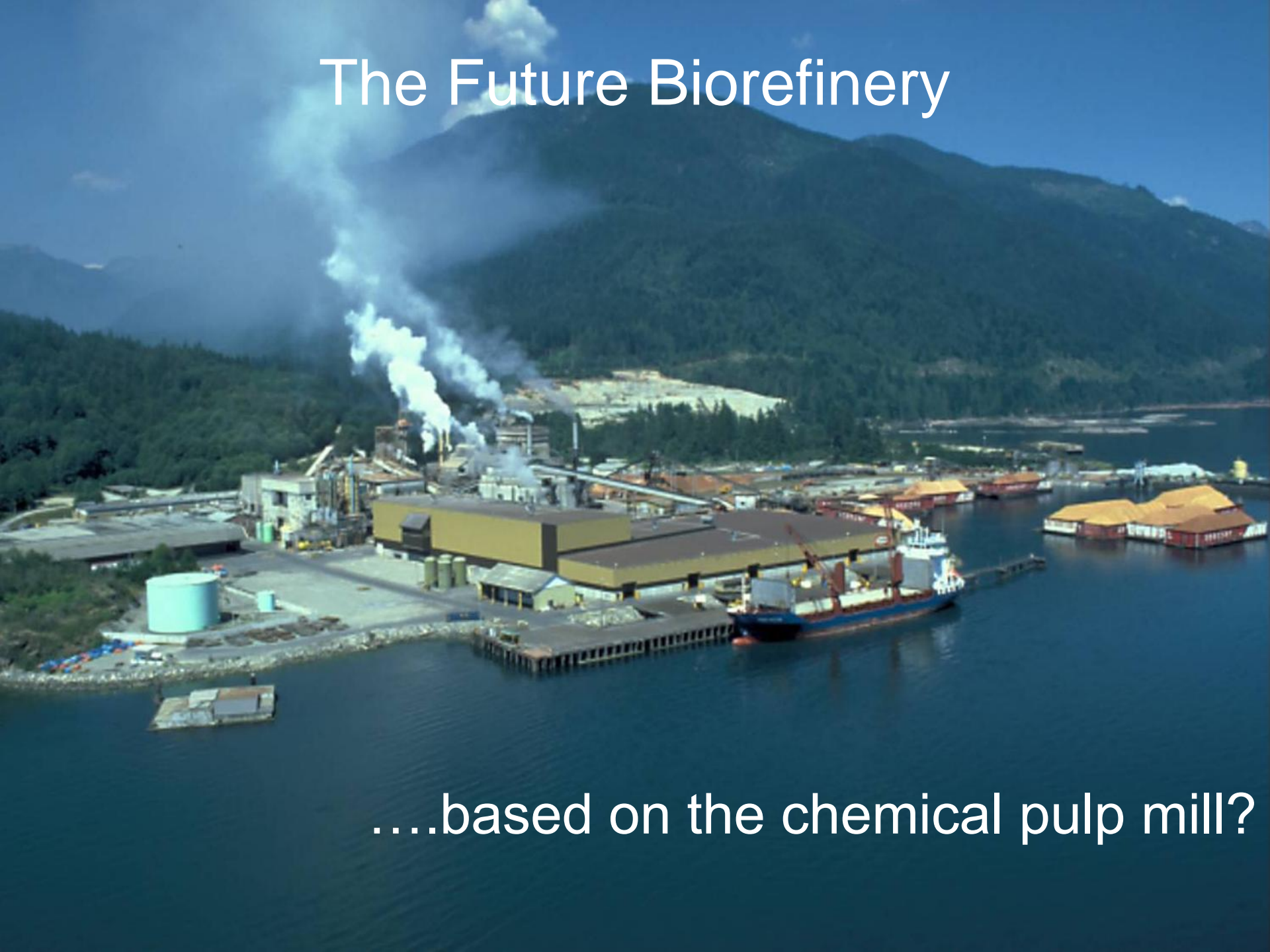
Traditional Byproducts from Sulfite Pulping

- Ethanol (Industrial and Fuel Grades)
- Lignosulfonates
 - Animal feed
 - Cement additive
- Protein
 - Torula yeast
 - Pekilo protein

Current Focus at FPInnovations

- Working with dissolving pulp mill to implement bioproduct diversification
- Investigating possibilities for conversion of other kraft mills
- Looking at new products based on analysis of hydrolyzates
- Separation and conversion technologies are needed
- Market size must be appropriate for mill capacity

The Future Biorefinery



....based on the chemical pulp mill?