




## Biorefinery within the pulp & paper sector

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Birmingham, December 2, 2009



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- Introduction
  - Lignin value chains
  - Hemicellulose value chains
  - 2nd generation ethanol
  - Black liquor gasification
  - Scenarios

## Drivers for pulp mill biorefining

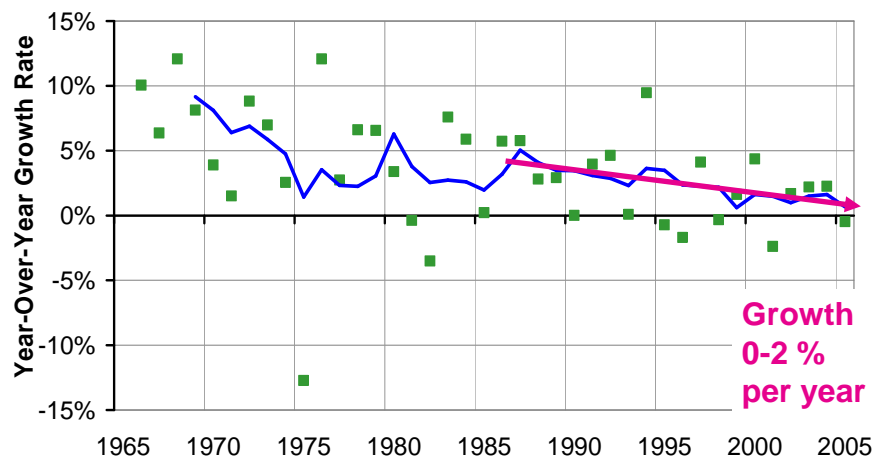
- Competition for biomass from the energy sector
- Processing of large volumes of biomass
- Infrastructure in place
- New efficient separation processes available
- Opportunities for new pulp mill products

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### Kraft Pulp Production Growth Rate (World)

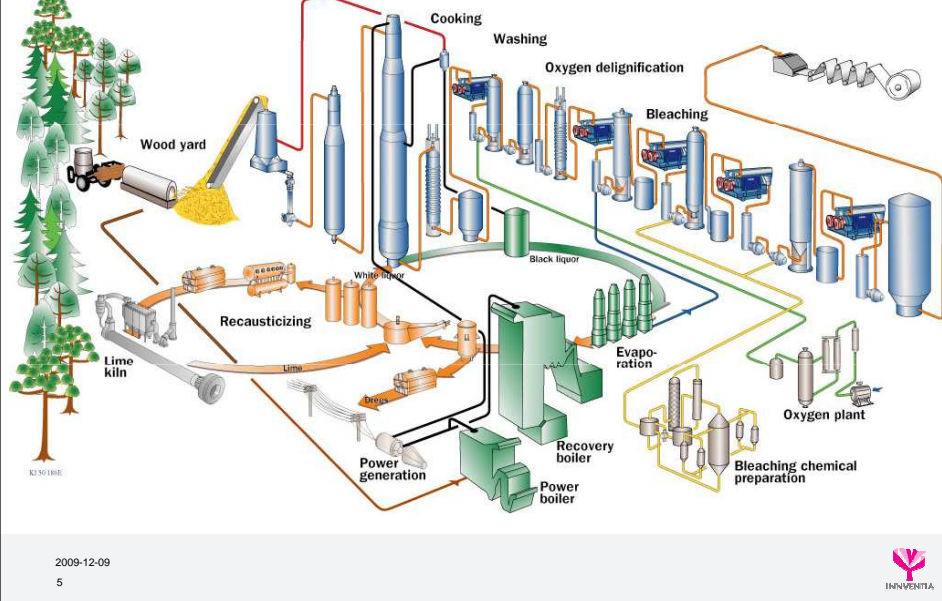


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## Chemical pulping process



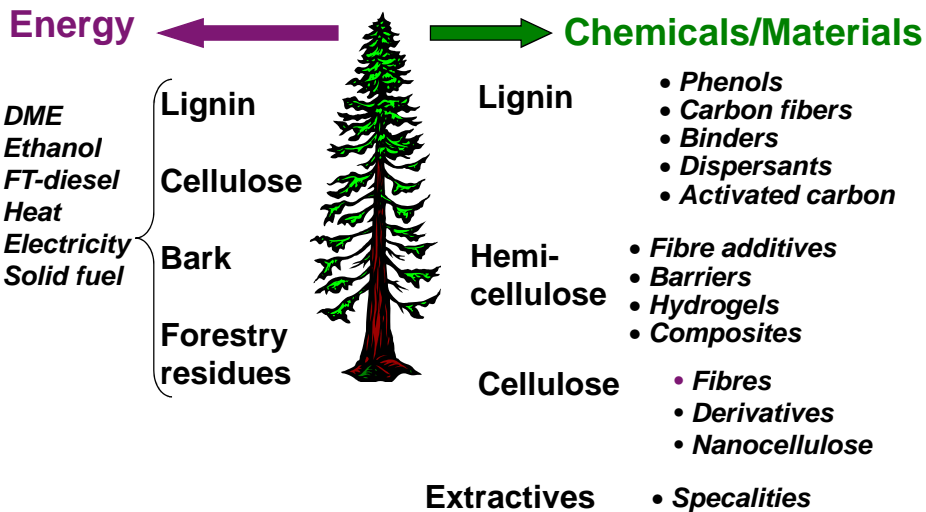
## Existing pulp mill alternatives

- Produce electricity for the power grid
- Produce heat for external users
- Remove lignin from black liquor
- Upgrade bark/forestry residues to solid fuel/pellets

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## Alkaline biorefining - Full utilization of wood

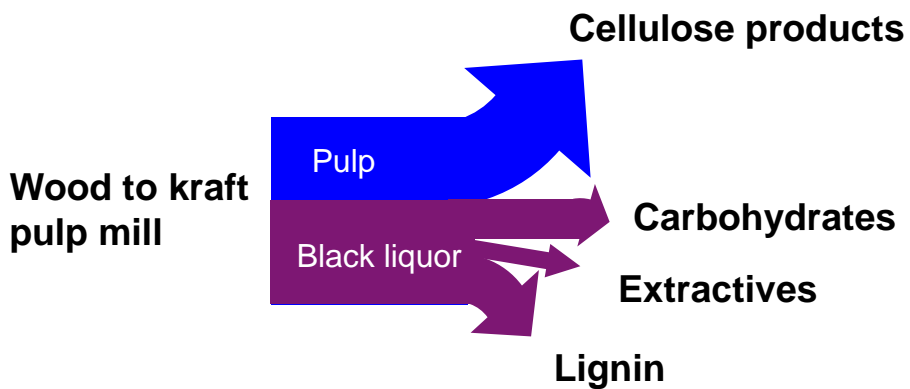


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## 50% of the wood ends up in cooking liquor



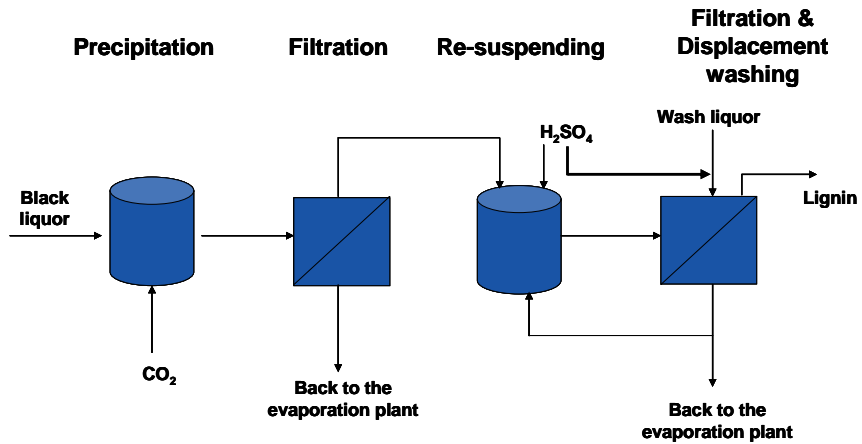
55-60 % of energy goes into the black liquor

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## The LignoBoost process

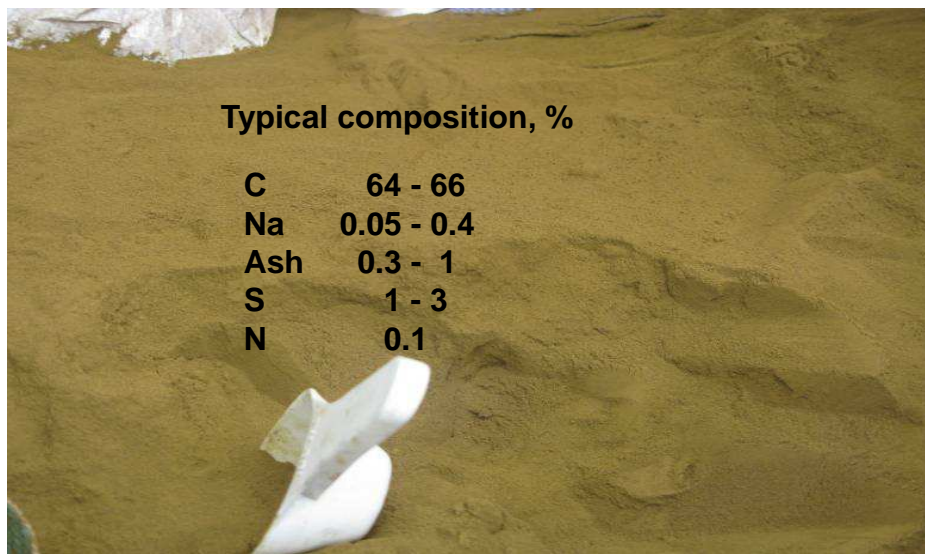


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## LignoBoost lignin – a new material



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## Potential kraft/soda lignin applications

Lignin in fuel oil



Lignin fuel in lime kilns



Lignin pellets



Dispersants



Kaolin/Water

Lignin to carbon fibres



Spun lignin fibres

### Other applications

- Binders
- Benzene/Phenols
- Activated carbon

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## Hemicellulose Applications

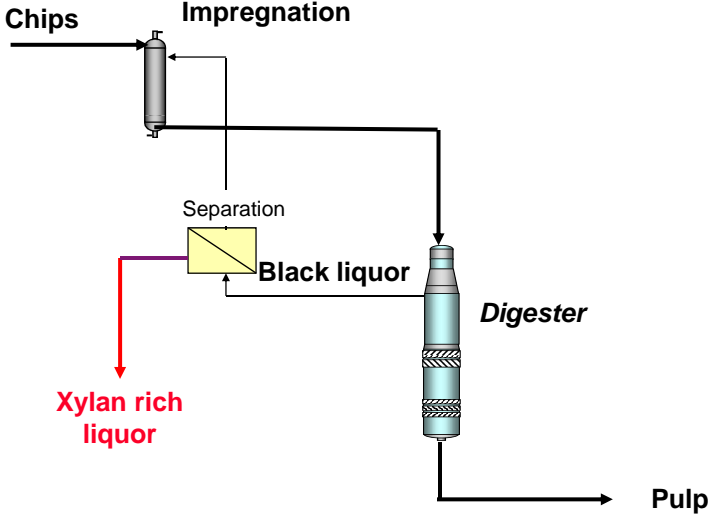
- Fibre functionalization
- Gas barrier
- Hydrogels
  
- Furfural
- Xylitol
- Sugar acids
- Emulsifiers
  
- Fermentation to succinic acid, ethanol etc.

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# Xylan from kraft black liquor



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# Hemicellulose - Nano-fibril cellulose composite films



Glucomannan based film

Xylan based film

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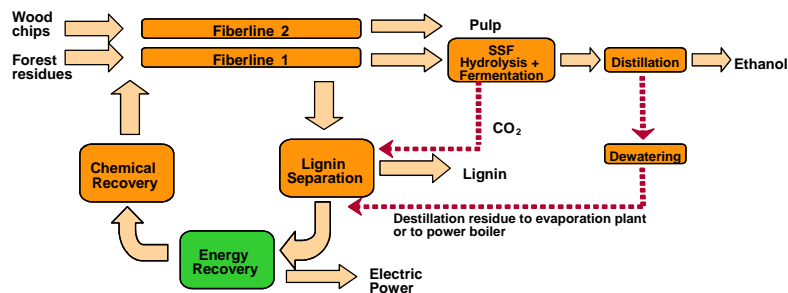
## Second generation ethanol

### ▪ Alkaline pretreatment

- can handle all wood/forestry residues/annual plants
- good separation of cellulose and lignin
- established technology

- Ethanol production in line 1

- Pulp production in line 2



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## Alkaline route from wood to ethanol

- Mostly known and well proven technology
- Fractionation allows optimal processing of lignin and carbohydrates separately
- Sulfur-free lignin as by-product
- Essentially closed loop with internal generation of chemicals
- Production costs on par with other process routes

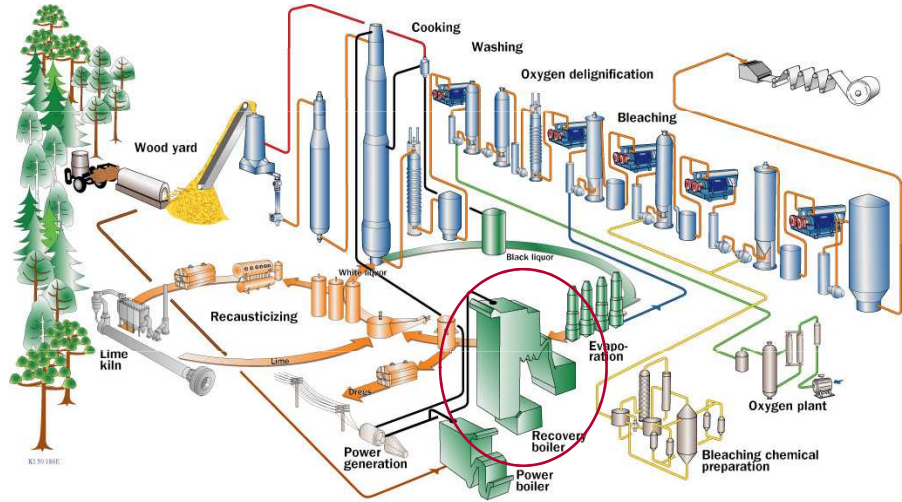
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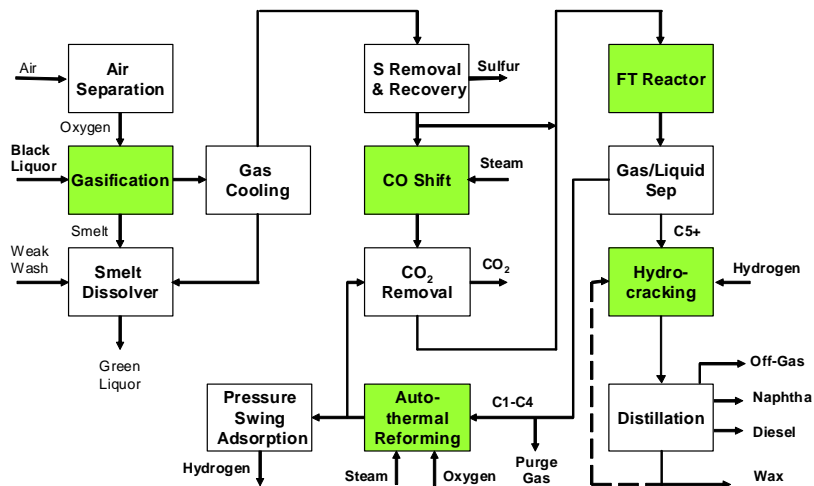
## Black liquor gasification



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## Black liquor gasification concept



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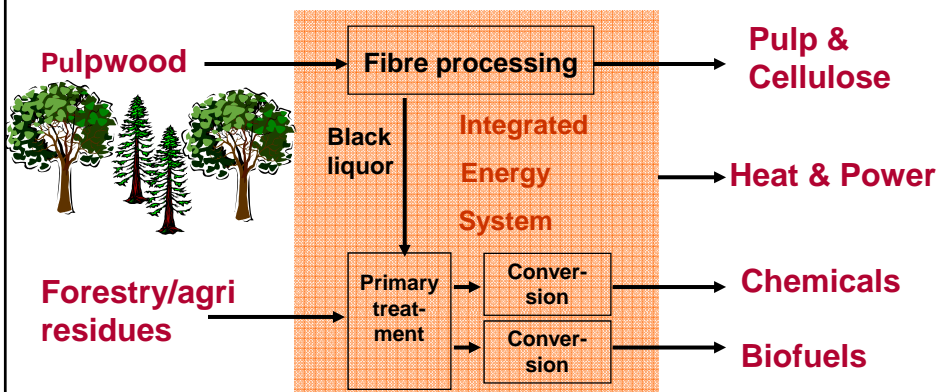
## Black liquor gasification - Balances

<i>Fuel options</i>	<i>Methanol</i>	<i>DME</i>	<i>FTD</i>
Biomass consumption	414 MW	408 MW	378 MW
Black liquor consumption	487 MW	487 MW	487 MW
Fuel production, total	273 MW	275 MW	244 MW
Fuel production, total	410,600 t/year	286,000 t/year	109,700 t/year (+56,200 t/year)
<i>Energy efficiency (LHV): Black liquor to fuel</i>	56%	56%	33% diesel + 17% naphtha
<i>Biomass to fuel</i>	66%	67%	43% diesel + 22% naphtha

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## The Future Pulp Mill Biorefinery - many options available



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## Implementation in kraft pulp mills 1-5 years

**Reference** Existing kraft pulp mill = platform

### Step 1

- 1-5 years**
- LignoBoost lignin
  - Hemicellulose from black liquor and wood
  - Ethanol from low value biomass

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## Implementation in kraft pulp mills 5 - 10 years

**Reference** Existing kraft pulp mill = platform

### Step 1

- 1 - 5 years**
- LignoBoost lignin
  - Hemicellulose from black liquor and wood
  - Ethanol from low value biomass

- Step 2**
- 5 -10 years**
- S-free lignin
  - Gasification concepts

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