



Case 3: Pulp & paper sector

Evaluation of innovative biorefinery concepts entering the pulp & paper industry

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Final BiOREF-INTEG Seminar

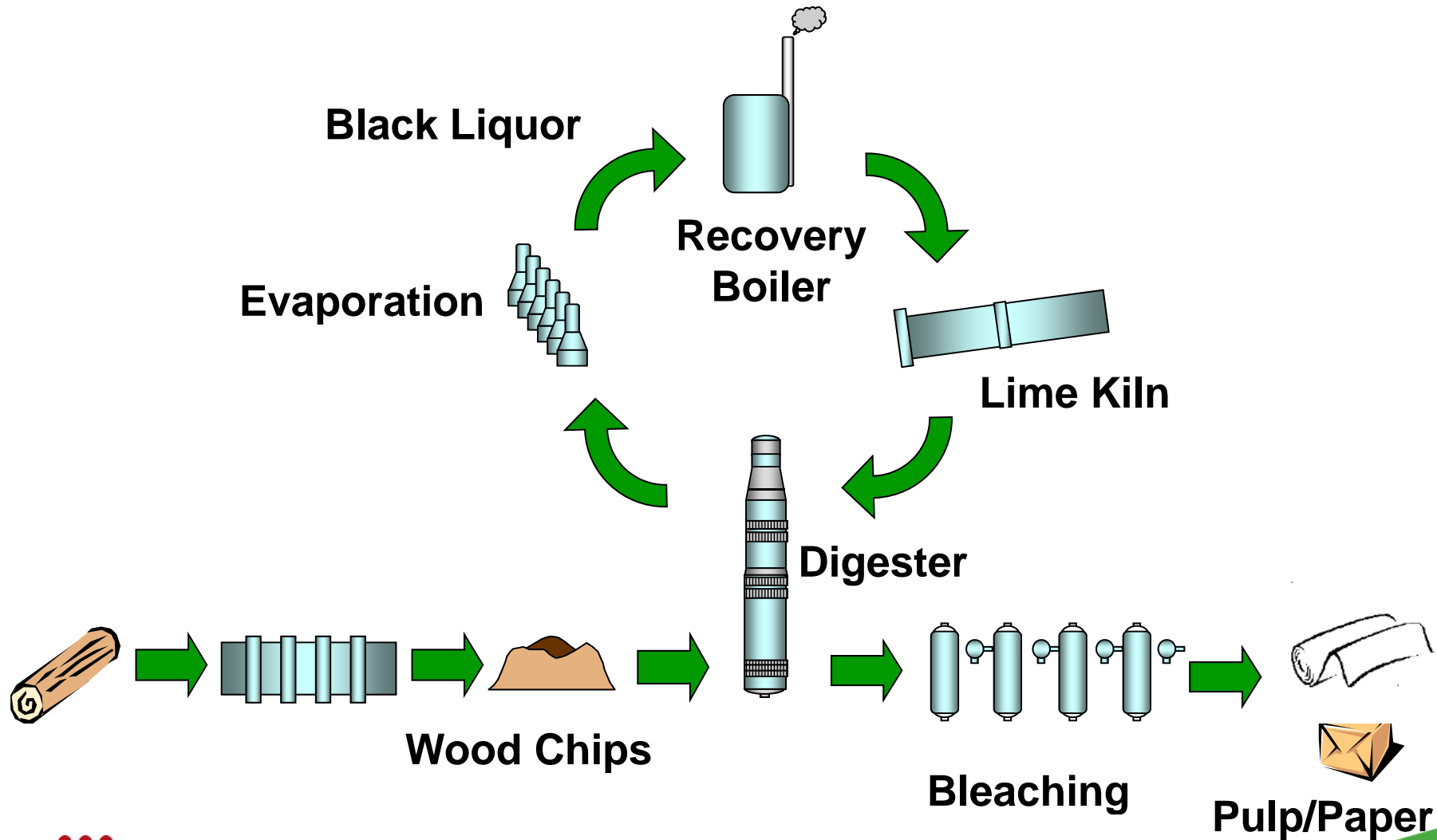
9 June 2010, Düsseldorf, Germany

Introduction

- Competition for biomass from the energy sector
- Competition from pulp producers in South America
- Demand for solid and liquid biofuels will increase rapidly in the coming years
- Processing large volumes of biomass
- Pulp mills often have an energy surplus
- Integration possible
- Existing infrastructure
- New efficient processes available



Reference case – Softwood pulp

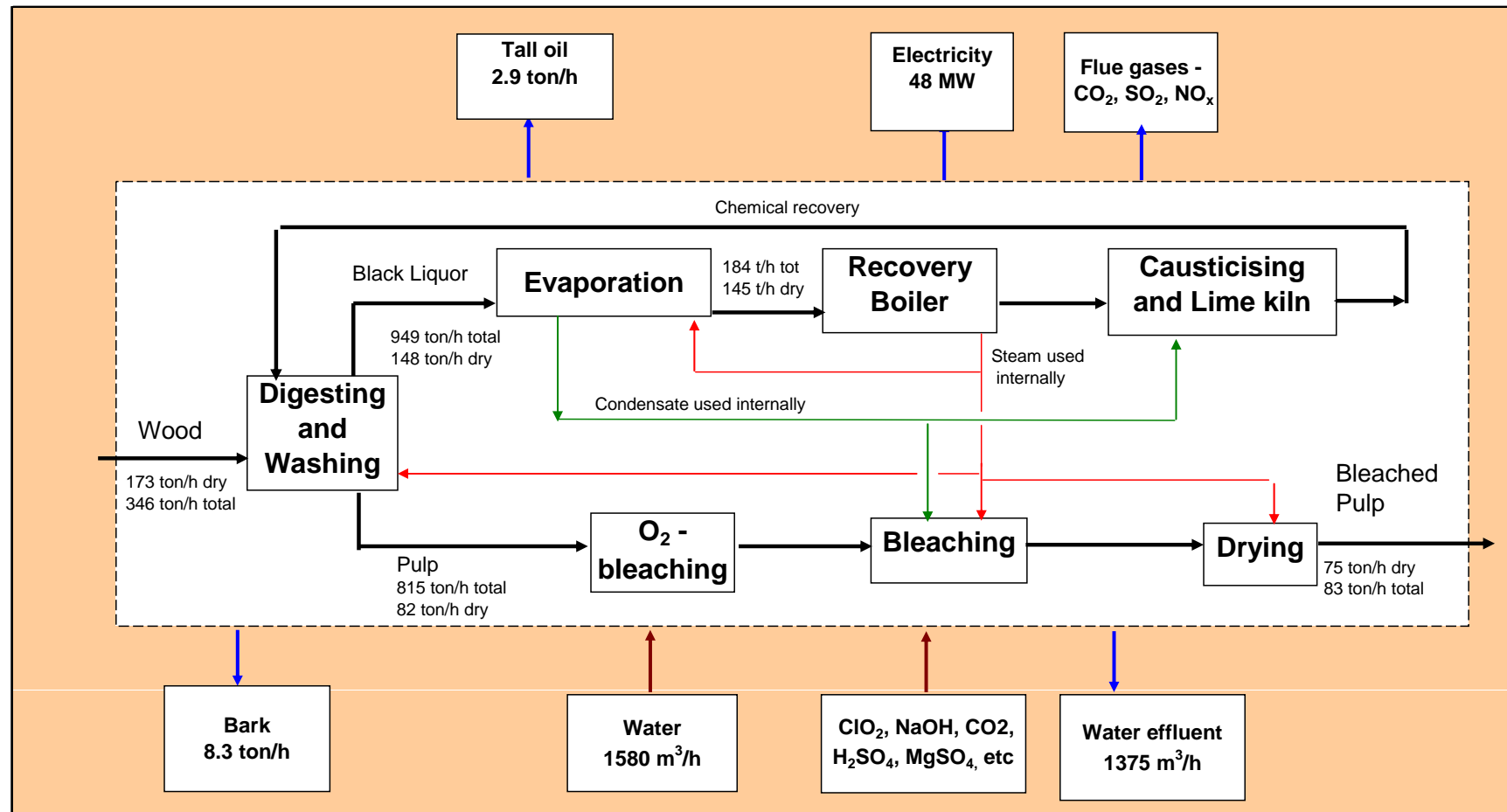


Reference case – Softwood pulp

- Theoretical mill with best available proven technique (2004)
- Raw material: 50% spruce and 50% pine (softwood)
- 1800 ton dry pulp / day
- Self sufficient in energy and electricity
- Condensing turbine
- Input: Softwood, water and chemicals (NaOH, H₂SO₄, ...)
- By-products: Tall oil, bark and electricity



Reference case – Softwood pulp



Integrated biorefinery case 1

Lignin extraction

- Lignin is precipitated from black liquor – LignoBoost process
- Recovery boiler load decrease
 - Up to 25% capacity increase possible
- Lignin can be utilized as lime kiln fuel (oil price)
- Other applications (carbon fibres, chemicals) will increase lignin price
- Production of 115 000 ton lignin/year possible in the reference case
- Chemical cost increase (CO_2 , H_2SO_4 , NaOH)
- Less steam and electricity produced

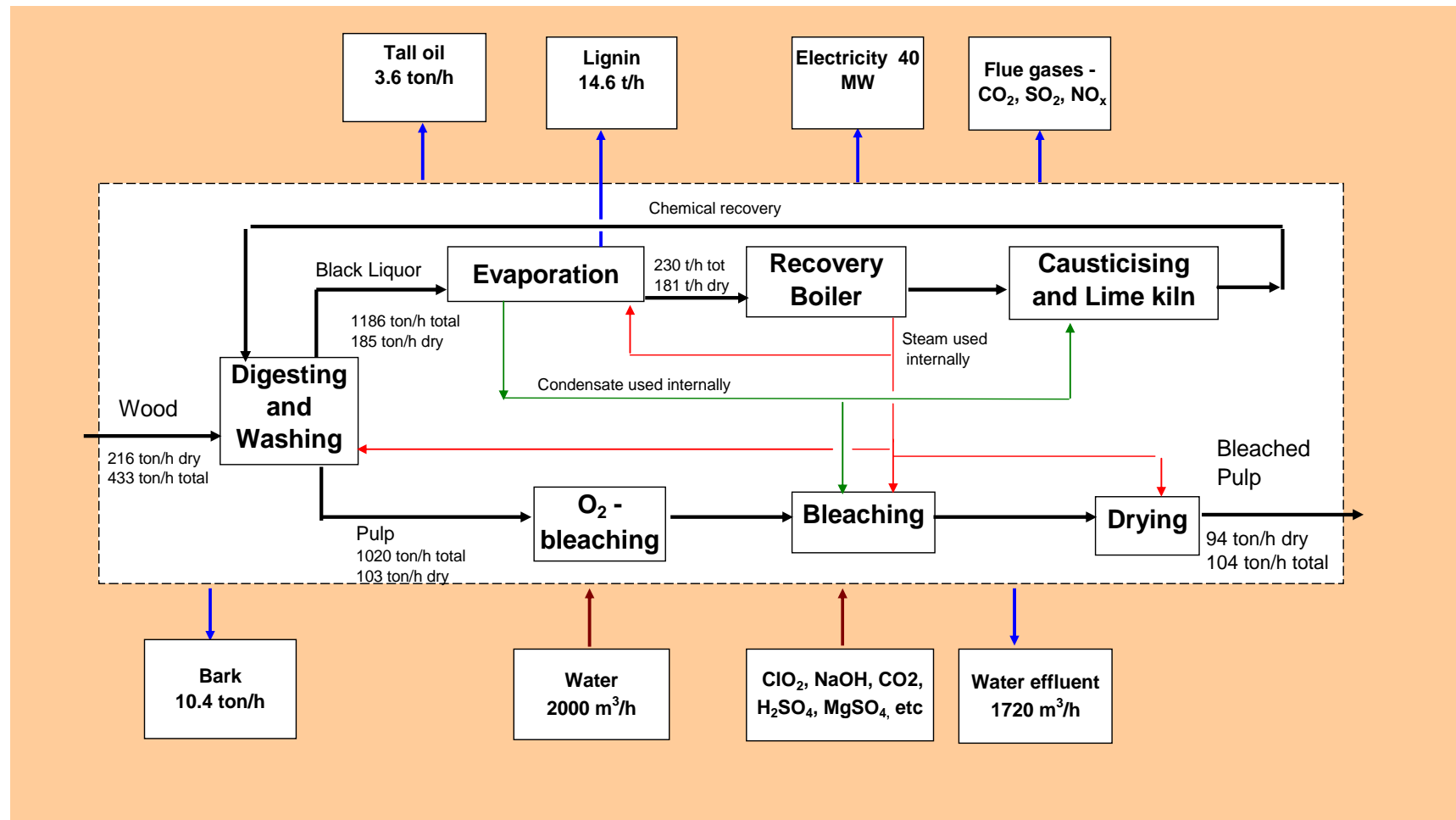


LignoBoost process in Bäckhammar

- Start-up 2007
- Produce 4000 t lignin/year
- Demonstrate the technology and produce lignin for combustion trials
- Low (0.1-0.8%) ash content
- LHV 26 GJ/tonne dry lignin

Integrated biorefinery case 1

Lignin extraction



Integrated biorefinery case 2

Black liquor gasification and DME production

- Recovery boiler replaced with a black liquor gasifier
- Syngas used to produce DME (methanol or FT-products possible)
- Cooking chemicals recovered in the bottom of the gasifier
- DME production of 285 000 ton / year possible
- Bark needs to be imported to produce the required amount of steam and electricity – much work carried out to decrease this amount



Demonstration of BLG - DME production

- Chemrec black liquor gasifier
- Haldor-Topsoe DME synthesis
- Planned production: 4 t DME/d
- Planned start-up: September 2010



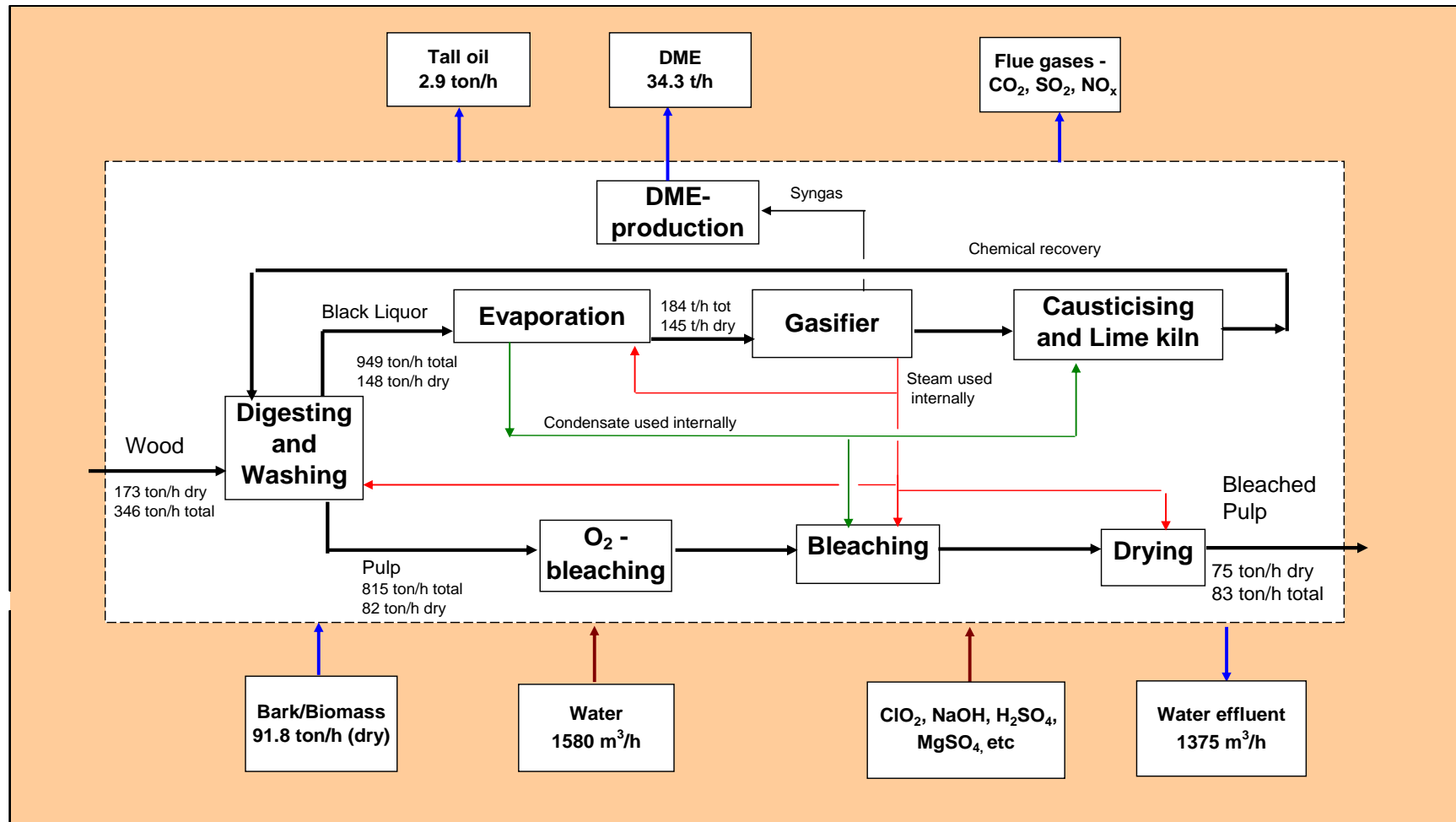
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Integrated biorefinery case 2

Black liquor gasification and DME production



Integrated biorefinery case 3

Ethanol production

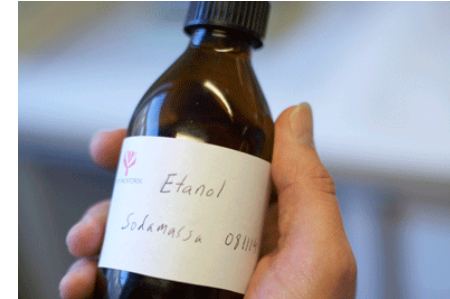
- One pulp production line and one ethanol production line
 - Pulp production reduced with 50%
- Fractionation allows optimal processing of lignin and carbohydrates separately
- Can handle all wood/forestry residues/annual plants
- In old mills much of the equipment from pulp production can be used
- Enzymes and yeast required
- Large amounts of COD to effluent



Ethanol production in a pulp mill

Concept verified in a full scale test

- Tested in mill and pilot scale trials

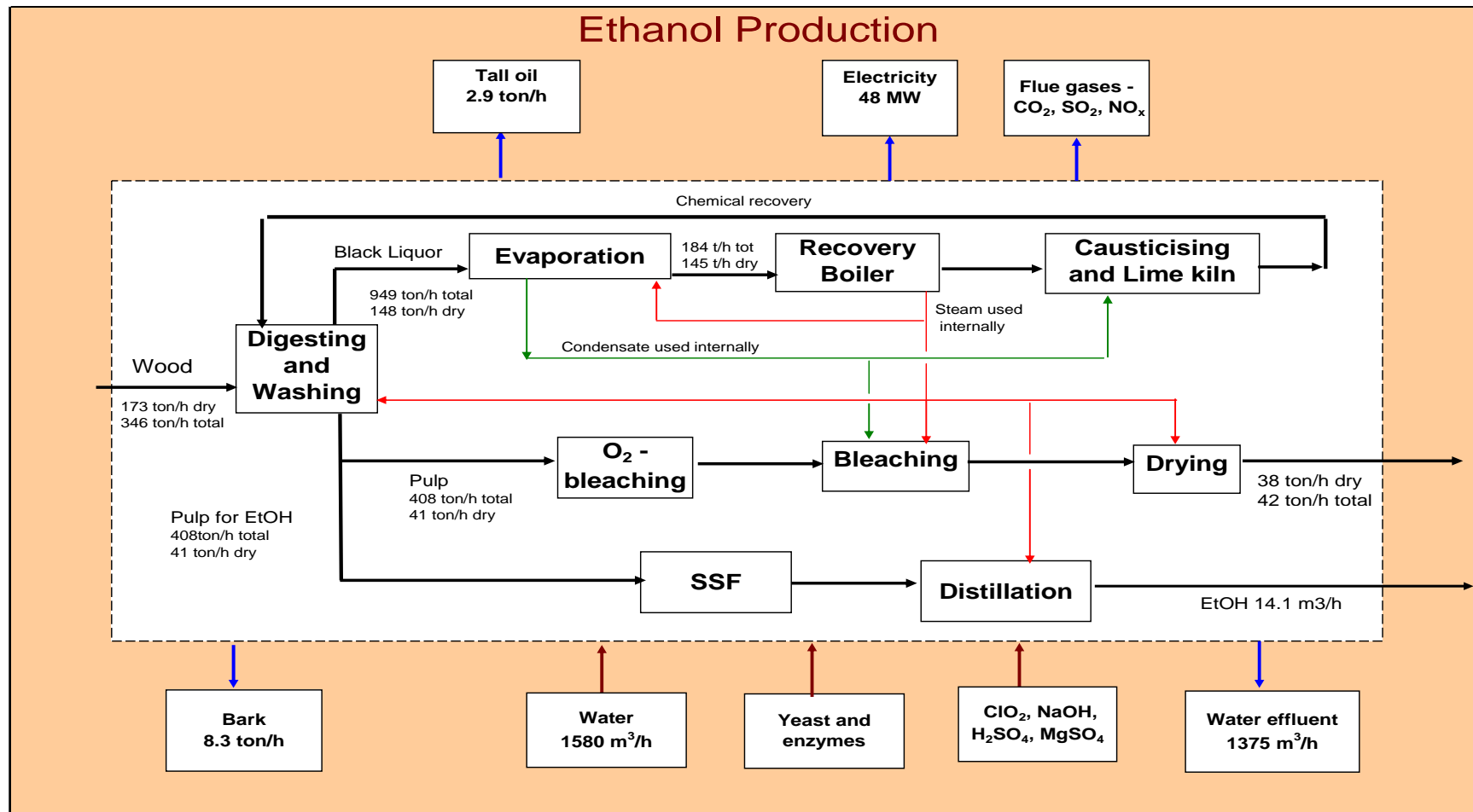


- Pilot plant in Örnköldsvik, Sweden



Integrated biorefinery case 3

Ethanol production



Overview – All cases

	Reference case	Lignin extraction	BLG/DME	Ethanol co-produced
Main product(s)	Pulp	Pulp and lignin	Pulp and DME	Pulp and ethanol
By-products	Tall oil, bark and electricity	Tall oil, bark and electricity	Tall oil	Tall oil, bark and electricity
Investment cost (MEUR)	715	795	1065	600
Capacity biorefinery (annual)		115 000 tonne lignin	285 000 tonne DME	110 000 m3 EtOH
Effects on main process of biorefinery installation		Larger capacity, less electricity, more chemicals	Biomass import, no electricity	More effluent, lower pulp production



Results techno-economic assessment

Main product		Pulp			
Scale		588 000 T/y			
	Description	Unit	€/unit	Unit/Tpulp	€/T pulp
Raw material Chemicals	Pulp wood	T	75.00	2.30	172.5
	Sodium hydroxide	T	400.00	0.03	10.8
	Magnesium sulphat	T	200.00	0.00	0.6
	Chlorine dioxide	T	700.00	0.01	5.6
	Hydrogen peroxide	T	400.00	0.02	6.0
	Oxygen	T	35.00	0.03	0.9
	Sulphuric acid	T	70.00	0.01	0.5
					Total auxiliaries
Water		T	0.1	21.00	1.1
					0.0
Co-products	Tall oil	T	200.00	0.04	-7.8
	Bark	T	70.00	0.11	-7.7
	Electricity	kWh	0.03	640.00	-19.2
Variable cost					163.2
Capex	715 000 000 €				
Depreciation	12 years				101.3
Labour	500 #		100 000.00		85.0
Other costs	5% % of capex				60.8
Fixed costs					247.2
Total (100% dry)					410.4
Market pulp (90% dry)					369.3



Results techno-economic assessment

- **Reference case – Softwood pulp**
 - Pulp production cost: 370 EUR/tonne (90% dry)
- **Biorefinery case 1 - Lignin extraction**
 - Pulp production cost: 320 EUR/tonne (90% dry)
- **Biorefinery case 2 – Black liquor gasification / DME**
 - Pulp production cost: 330 EUR/tonne (90% dry)
- **Biorefinery case 3 – Ethanol production**
 - Pulp production cost: 570 EUR/tonne (90% dry)
- Market price 2005-2010: 400-800 EUR/tonne (90% dry)



Technical feasibility

- Lignin produced in a demonstration plant
- BLG/DME complex technology and DME not yet accepted
- Ethanol slightly above average

	Lignin extraction	BLG / DME	Ethanol	Project average
Technical feasibility	79.8	62.0	72.3	70.7



Commercial feasibility

- Lignin extraction and BLG/DME highly attractive – both products will lead to an economical benefit for the user
- Ethanol case slightly above average – attractive in old mills

	Lignin extraction	BLG / DME	Ethanol	Project average
Commerical feasibility	83.3	82.8	74.0	71.0



SWOT analysis

Lignin extraction

- **Strength**
 - Production of lignin in demonstration plant
 - 25% pulp production increase possible
- **Weaknesses**
 - Increased chemical costs
 - Lower electricity export
- **Opportunities**
 - Increased oil price
- **Threats**
 - Pulp demand decreasing which makes the capacity increase less relevant



SWOT analysis

Black liquor gasification and DME production

- **Strength**
 - Economics of integrated concept is promising
 - Two products – Pulp and DME
- **Weaknesses**
 - Complex technology
 - Large investment costs required
- **Opportunities**
 - Increasing oil price
 - Acceptance of DME by EU countries as biofuel
- **Threats**
 - High electricity price
 - No acceptance of DME by EU countries as biofuel



SWOT analysis

Ethanol production

- **Strength**
 - Platform for 2nd generation fermentation
 - This concept can be applied to old pulp mills
- **Weaknesses**
 - Less efficient process (yield wood-to-ethanol via pulp)
 - More by-products to take care of (CO₂, organic residues)
- **Opportunities**
 - Increasing oil price
- **Threats**
 - Enzymes to hydrolyse wood to sugars isn't commercially available
 - Alternative routes to biofuels from wood



Summary and conclusions

- **Reference case – softwood pulp (370 EUR/tonne)**
- Three biorefinery cases evaluated:
 - **Lignin extraction (320 EUR/tonne)**
 - Good technical and commercial feasibility
 - **Black liquor gasification (330 EUR/tonne)**
 - Good commercial feasibility – below average on technical feasibility
 - **Ethanol production (570 EUR/tonne)**
 - Average commercial and technical feasibility
- All case are interesting options for increasing competitiveness in the pulp & paper industry

