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Towards large, fossil free mills with integrated biorefineries – trends in modern pulp mills

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Introduction

Kraft pulping still strong but bioproducts emerging

Energy efficiency and electricity production

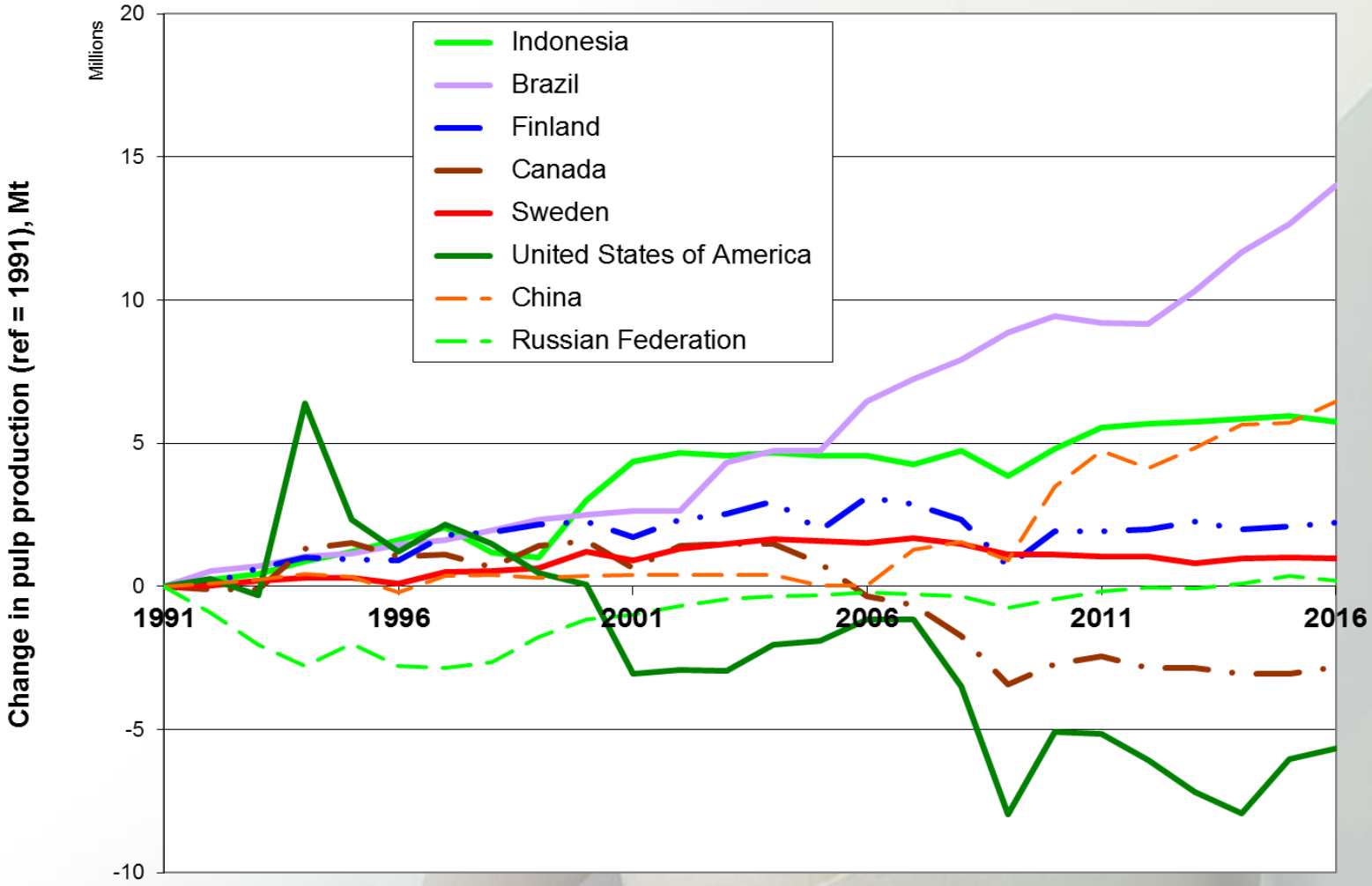
Bigger pulp mills

Reduction of CO2 footprint

Where are we going

- Changes Kraft pulping are occurring at breathtaking place.
- Environmental pressures force mills to reduce emissions to air and water and look at sustainable management of biomass resources.
- Recent Paris 2015 Agreement has forced the industry to find new ways to reduce its already low CO2 footprint. Targets require the pulp industry to have replaced fossil fuel based carbon dioxide emissions by 2050.
- The economic trends require pulp mills to be larger and to produce more energy. This is clearly shown by e.g. several just started pulp mills in Brazil that are over 1 000 000 ADt/d.

Change in wood chemical pulp production in selected countries, data from FAO 2016



Bioproducts are coming

- The competitive pressure requires moving from production of single commodity to offering multiple renewable bioproducts.
- The companies must reinvent themselves as networked entities co-operating with several added-value products.
- Firstly to manufacture **transportation fuels** to replace fossil fuels.
- Secondly to manufacture **biofuels** like white of black pellets to be used in traditional production of electricity and heat.
- To produce new **biomaterials**. New packaging materials, fibers for clothes, materials to be used in automotive industry and additives for pharmaceuticals are already taking off.

Reference mill

To clarify some of the suggested changes mass and energy balances have been calculated to a reference mill. The studied mill produces 1.5 MADt of hardwood pulp in 350 annual operating days.

Main process values for the reference mill

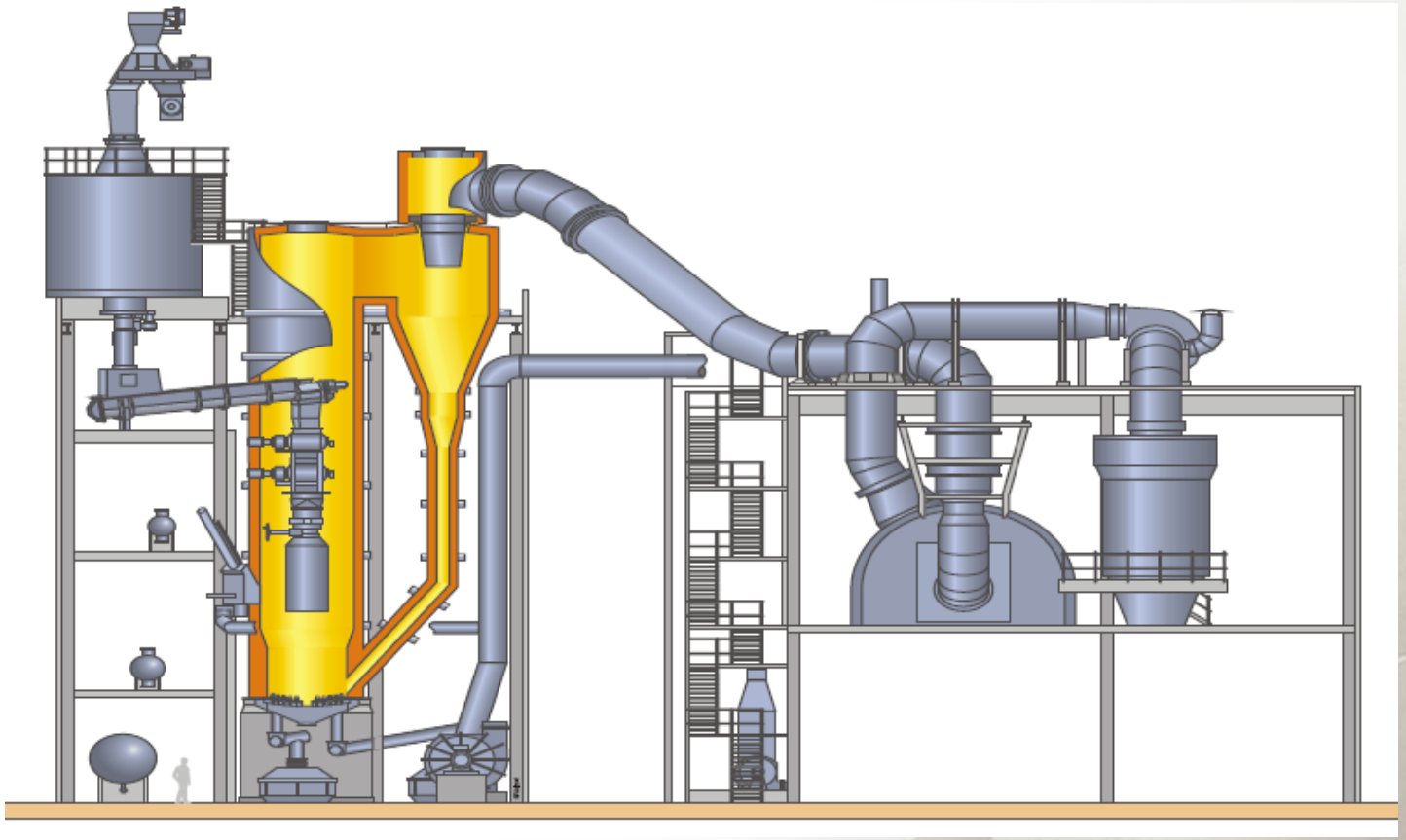
		Unit	Base case mill
Production	-Operating hours	h/a	8400
	-Bleached pulp production	ADt/d	4560
Wood handling	-Wood income	m^3sob/d	24370
	-Residue generated	BDt/d	567
	-Wood moisture	%	50
Recovery boiler	-Solids as fired	BDt/d	7266
	-Net steam flow	t/h	1021
Power boiler	-Woody biomass fuel use	BDt/d	567
	-Net steam flow	t/h	116
Lime kiln	-Product	t/d	1128
	-Heat requirement	MW	72
	-Oil consumption	t/d	143
Energy	-Steam use in pulp mill	t/h	860
	-Power generation	MW	195
	-Power consumption in pulp mill	kWh/ADt	609

Fossil fuel free operation

- In modern kraft pulp mills, most of the energy is biomass-based. Fossil fuels are used in lime kilns and to minor extent during upsets, start-up, and shutdown.
- Recent Paris 2015 Agreement has forced the industry to search new ways to reduce its already low CO2 footprint.
- Methanol, turpentine and hydrogen have been successfully fired in lime kilns. Firing biomass as pulverized or as biogas from gasification has started to gain acceptance.
- Changes of the lime kiln fuel affects the whole causticization; fluctuations in fuel flow, heating value and moisture content can create problems as the temperature profile of the lime kiln changes causing ringing.

Bark gasifier for lime kiln

(Courtesy of Valmet)



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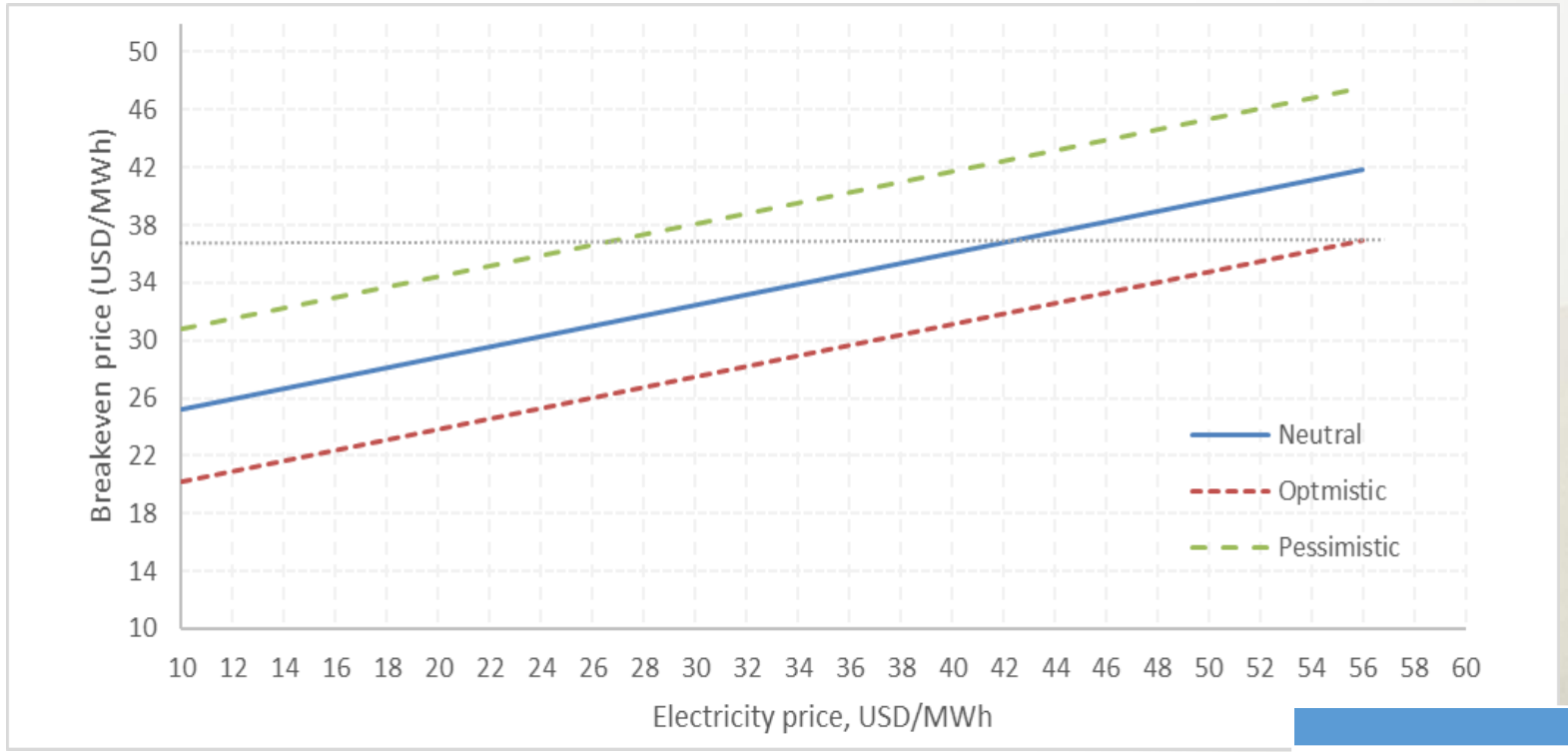
Breakeven lime kiln fuel price for gasification



	Unit	Gasification		
Scenario		Neutral	Optimistic	Pessimistic
Add- biomass	BDt/d	283	283	283
Electricity	$/MWh	35	25	45
Interest rate	%	10	8	12
Investment	M$	42	34	50
Biomass	$/t	6.2	3.2	12.5
Make-up lime	$/t	180	180	180

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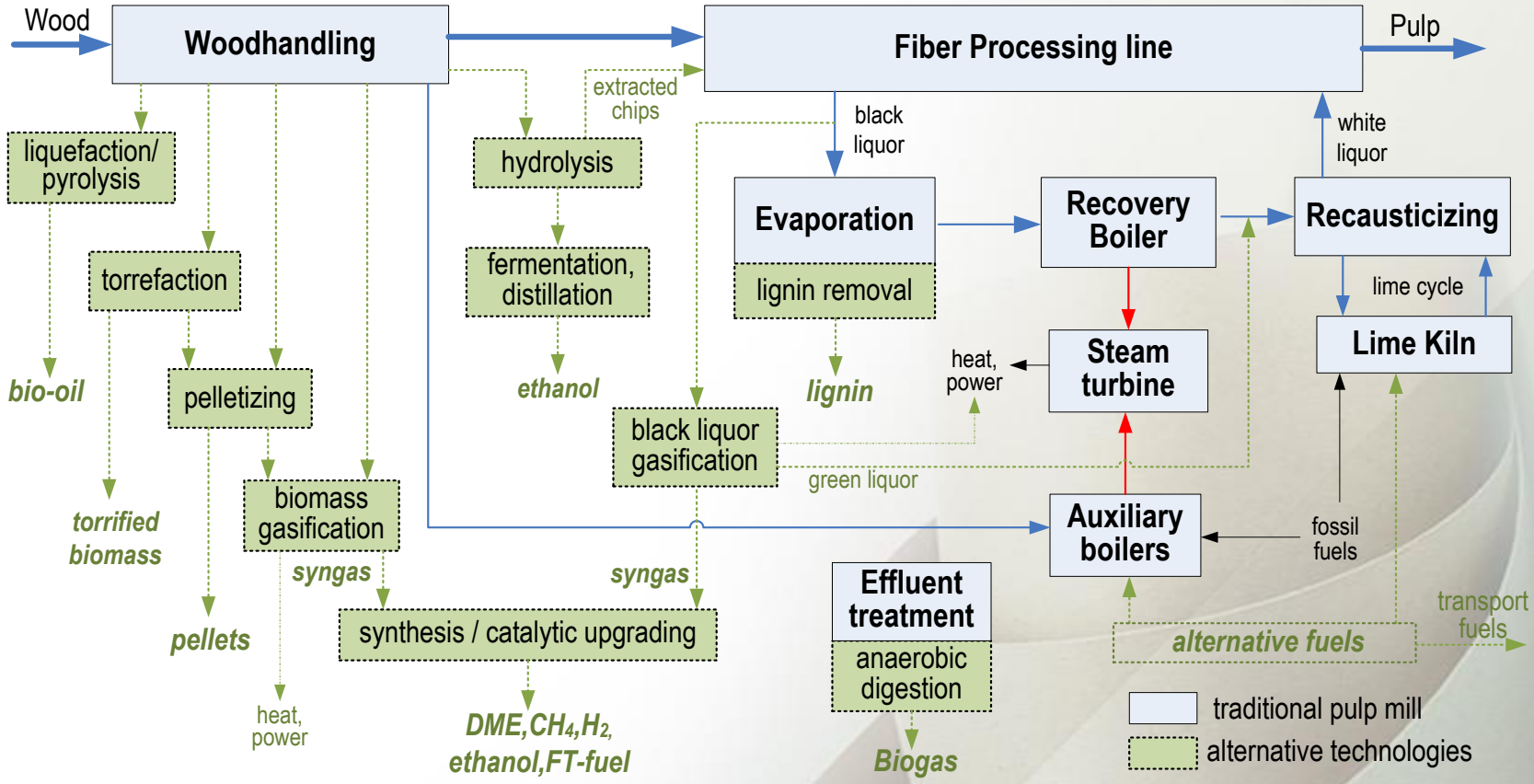
Bioproduct mill

The modern trend is to try to add additional process to kraft process to gain more revenue. Processes installed commercially include e.g. lignin removal, biogas production and biomaterials production .

Some possible biorefinery options in a kraft mill



(Hamaguchi *et al.* 2012)

An industrial lignin separation plant at Domtar, Plymouth

(Tomani 2013)

Production of transport fuels

- Combining biomass gasification and Fischer-Tropsch (FT) synthesis plant was seen as a way to produce syncrude.
- Lappeenranta, Kaukas mill makes transport biofuel BioVerno from tall oil, 100 000 tons of fuel per year.
- SunPine company in Piteå has a 100 000 tons of fuel per year plant.
- BioSNG can be produced by gasifying and purification. Joutseno mill in Lappeenranta obtained an environmental permit for this.
- Biogas can be produced by anaerobic gas production from e.g. biosludge. EcoEnergy does this at Äänekoski mill, capacity is about 25 GWh of biogas per year with yield of about 30%.

New operating model

- Building a feasible renewable bioproduct plant is not easy and requires specialist know-how.
- Up until the 1970s pulp mills produced multiple products
- Then they transferred to one product only mode.
- Co-existence and dependency from main product are known business models from e.g. car industry.
- The pulp industry has practiced this with new chemical plants located beside some of the new pulp mills. This mode of operation needs to be extended to other, biobased products.

NEGATIVE CO2 WITH BECCS

To reduce global warming decarbonisation should be done fast. Considerable negative emission technologies need to be deployed. Main alternative is capturing carbon dioxide emissions from biobased processes (BECCS).

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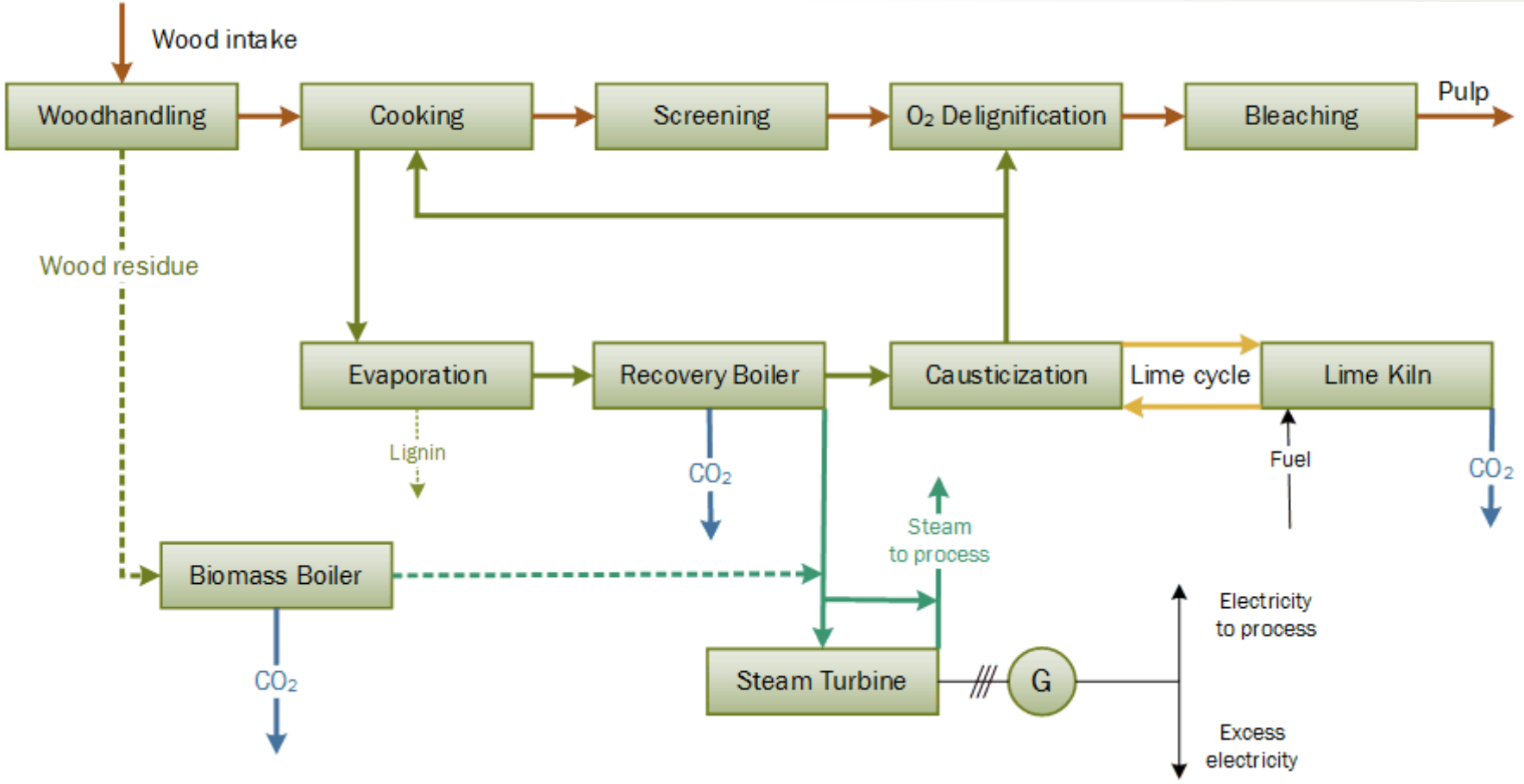
Sources of CO_2



Even a small capture* makes pulp mills negative emitters

$$CO_{2,net} = (C_f + C_{CaCO3}) \frac{M_{CO2}}{M_C} - \eta_{CCU}\eta_{CC}CO_{2,total}$$

*CO_2 from bio is carbon neutral

For the studied Mill, where the capture process is applied only on recovery boiler, substantial 2.4 Mt,CO2/ADt recovery potential for the biobased CO2 is found. Specific emissions, however, have large variation, depending on capture process efficiency and the CO2 emissions of the utilization route

CO_2 removal methods

- Different technologies can be utilized for CO_2 capture from pulp mills.
- Amine-based post combustion CO_2 capture systems are a proven technology that is commercially available.
- CO_2 capture using monoethanolamine (MEA) uses 3.7 MJ/kg,CO_2 heat for sorbent regeneration. As additional electricity is needed for the process, own electricity use of the mill increases.
- For Finnish pulp and paper sources the cost of biogenic CO_2 for utilization was estimated as 40 – 44 €/t,CO_2.

The effect of carbon capture process in the energy balances of reference mills

	Unit	Base	CO_2 capture
CO_2 capture	t/d	-	1881
Mill steam use	t/h	860	1008
Power generation	MW	195	179
Power consumption	MW	116	127

Multiproduct

Integrated biorefinery

Big

Flexible

New way to operate

Fossil-fuel free

Biogas

Bioproducts

High power

Conclusions

- Modern kraft pulp mills capacity is increasing at steady pace.
- The key to future success is the ability to constantly improve and adapt to needed changes.
- Pulp mills need to find ways to operate without fossil fuels.
- A new era of biorefinery-focused production is emerging.
- The world is going towards bioproducts and pulp mills that operate in new ways are a big part of the future.