LignoBoost Kraft Lignin

A New Renewable Fuel and a Valuable Fuel Additive

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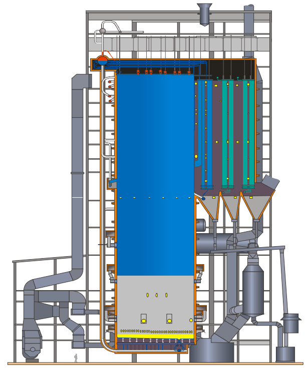
Outline

- Background – Introduction
- Kraft lignin – process & product
- Trials in different combustion applications
- Summary

Driving forces

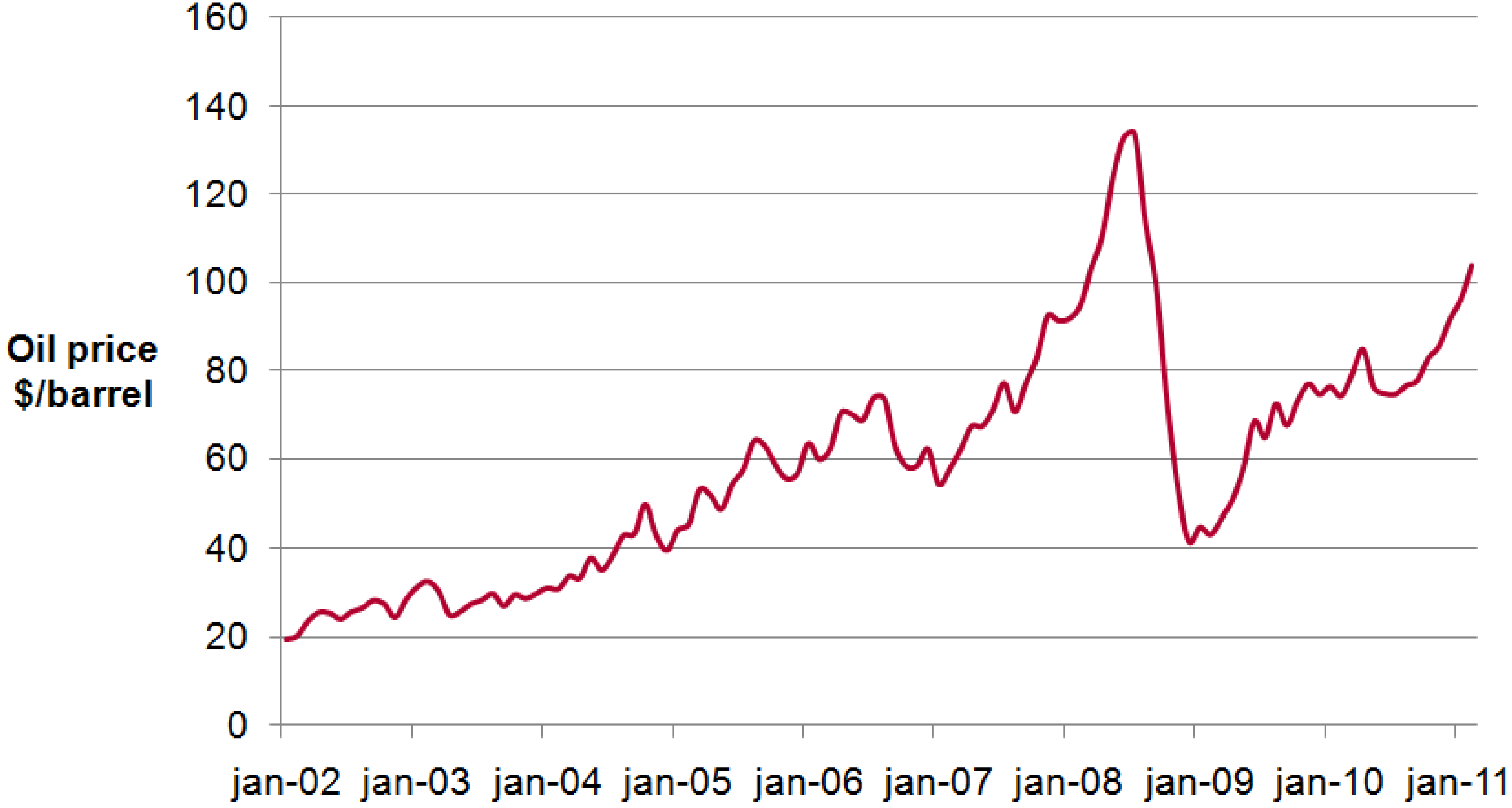
- **Increased pulp production**
  - By reduced thermal load in the recovery boiler



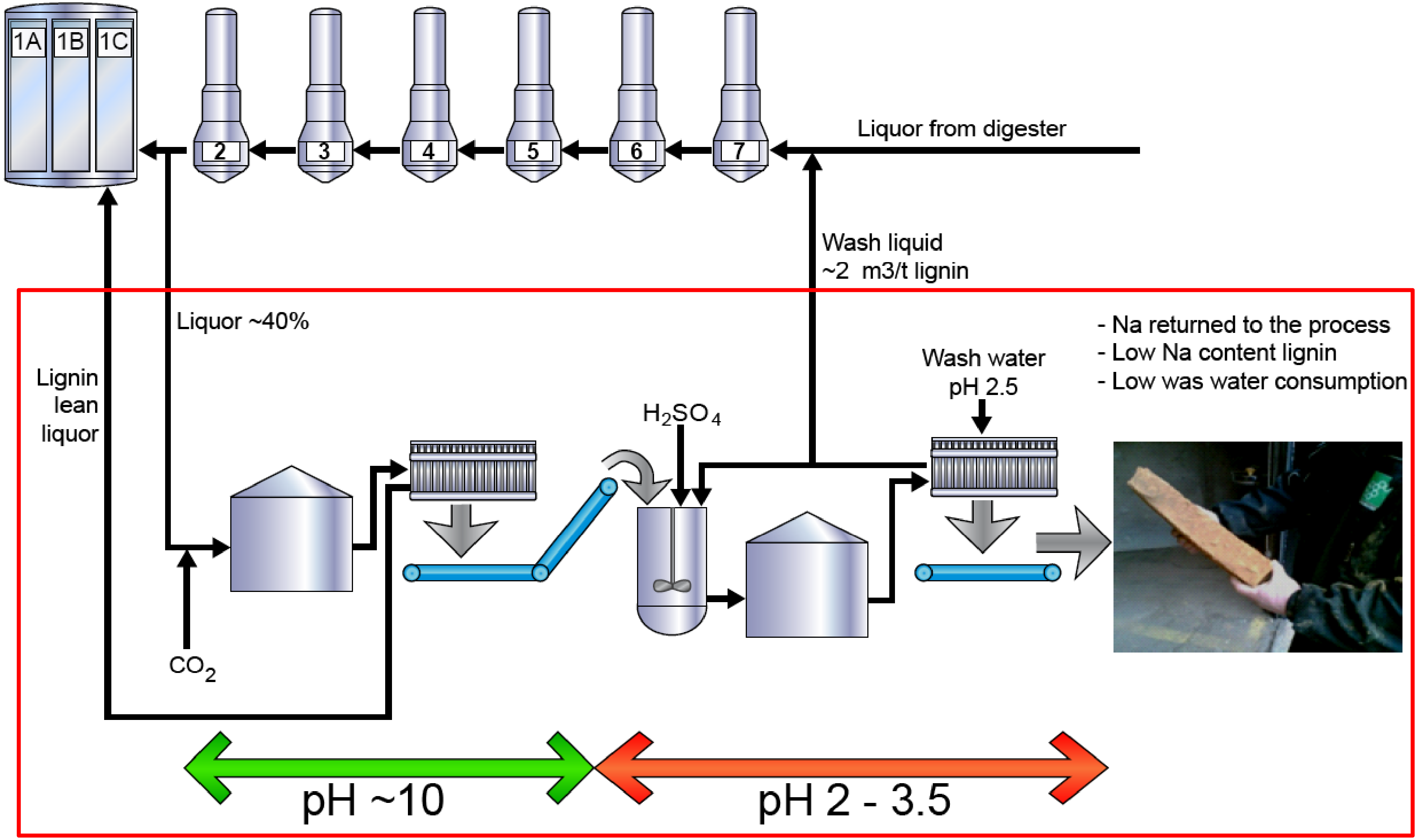
- **Reduced oil consumption – Go Green**
  - Replacement of fossil fuel in the lime kiln with lignin

- **Exporting revenue**
  - Excess energy can be exported from market pulp mills to external users - energy, chemicals & materials

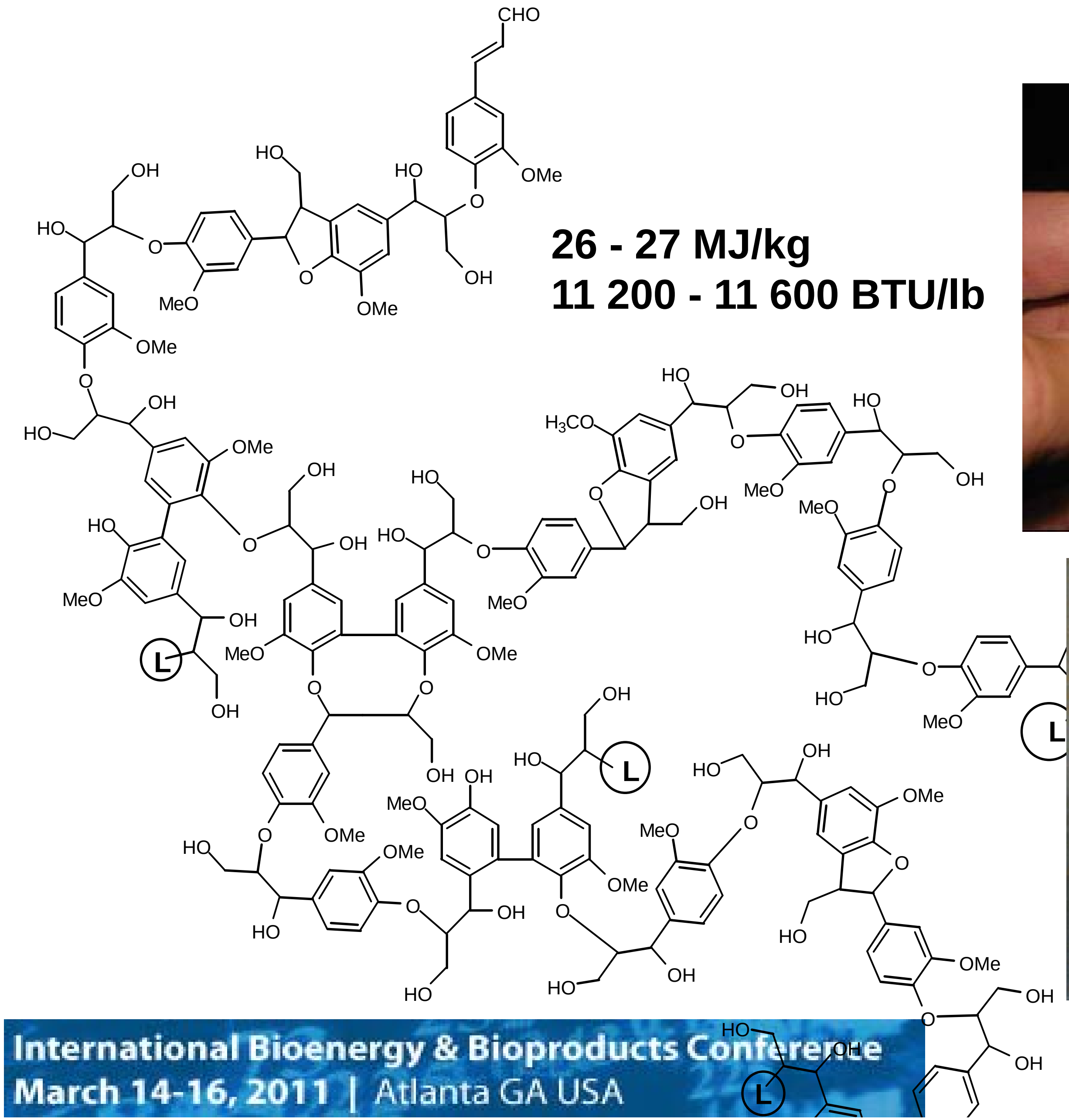
Oil price changes



The LignoBoost process



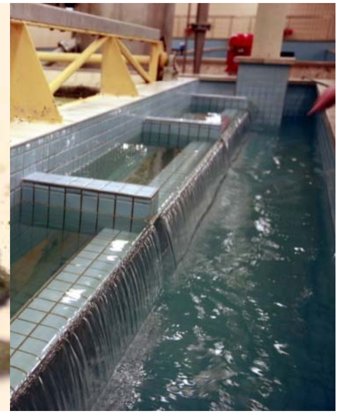
Kraft lignin properties & potential use?



26 - 27 MJ/kg
11 200 - 11 600 BTU/lb

Examples of potential products from kraft lignin



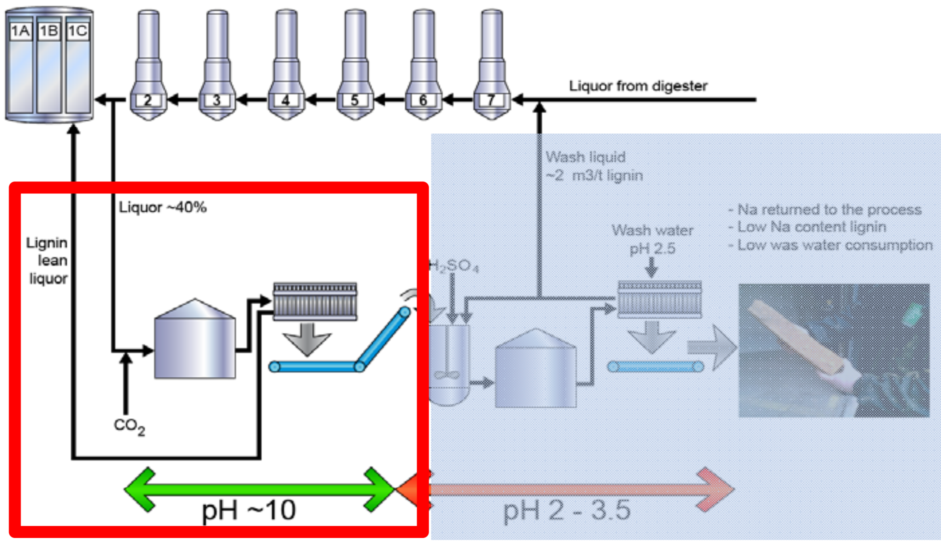






Pressfilter from Metso in our Demo plant in Bäckhammar, Sweden

Process: comments & experiences

- First part of the LignoBoost-concept:
  - Commercial operation 1994 to 2005.
  - Product: 5-15% ash and 35% DS (waterslurry).
  - Continuous operation, one yearly maintenance stop.
  - Production of lignin on a level of 6 000 tonnes/year.

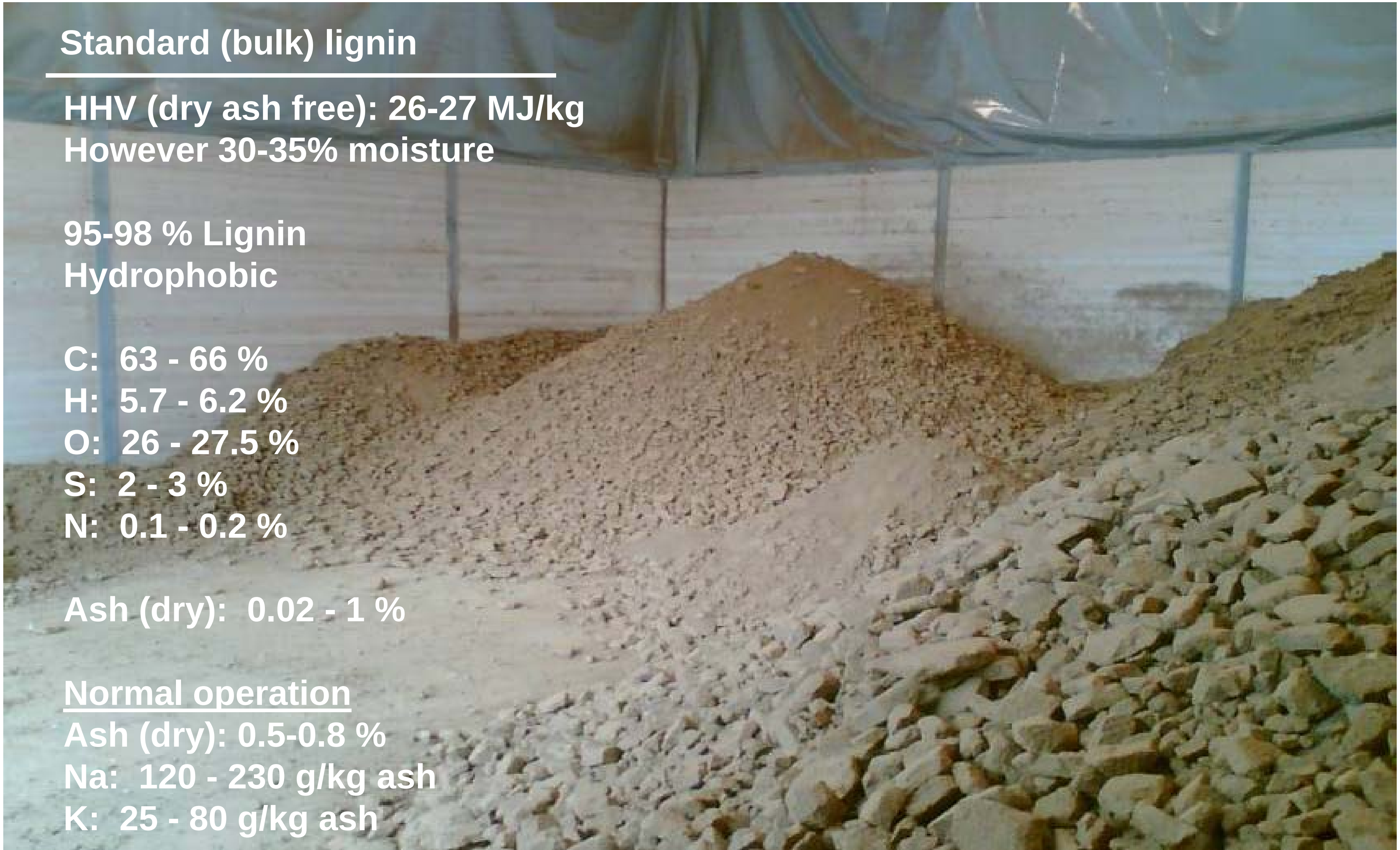


Process: comments & experiences

- The second part of the LignoBoost-concept:
  - Demonstration by Innventia on a level of 4 000 tonnes/year
  - Product: 0.02-1 % ash, 65-70+% DS
  - Operated 5 days a week 24 hours/day 2007-2008. Now focused on R&D.

- The LignoBoost-concept have no new equipment but a key component - press filters:
  - Well-proven equipment in the mineral industry. Fully automatic equipment.

Kraft lignin in our demonstration plant



Standard (bulk) lignin

HHV (dry ash free): 26-27 MJ/kg
However 30-35% moisture

95-98 % Lignin
Hydrophobic

C: 63 - 66 %
H: 5.7 - 6.2 %
O: 26 - 27.5 %
S: 2 - 3 %
N: 0.1 - 0.2 %

Ash (dry): 0.02 - 1 %

Normal operation
Ash (dry): 0.5-0.8 %
Na: 120 - 230 g/kg ash
K: 25 - 80 g/kg ash

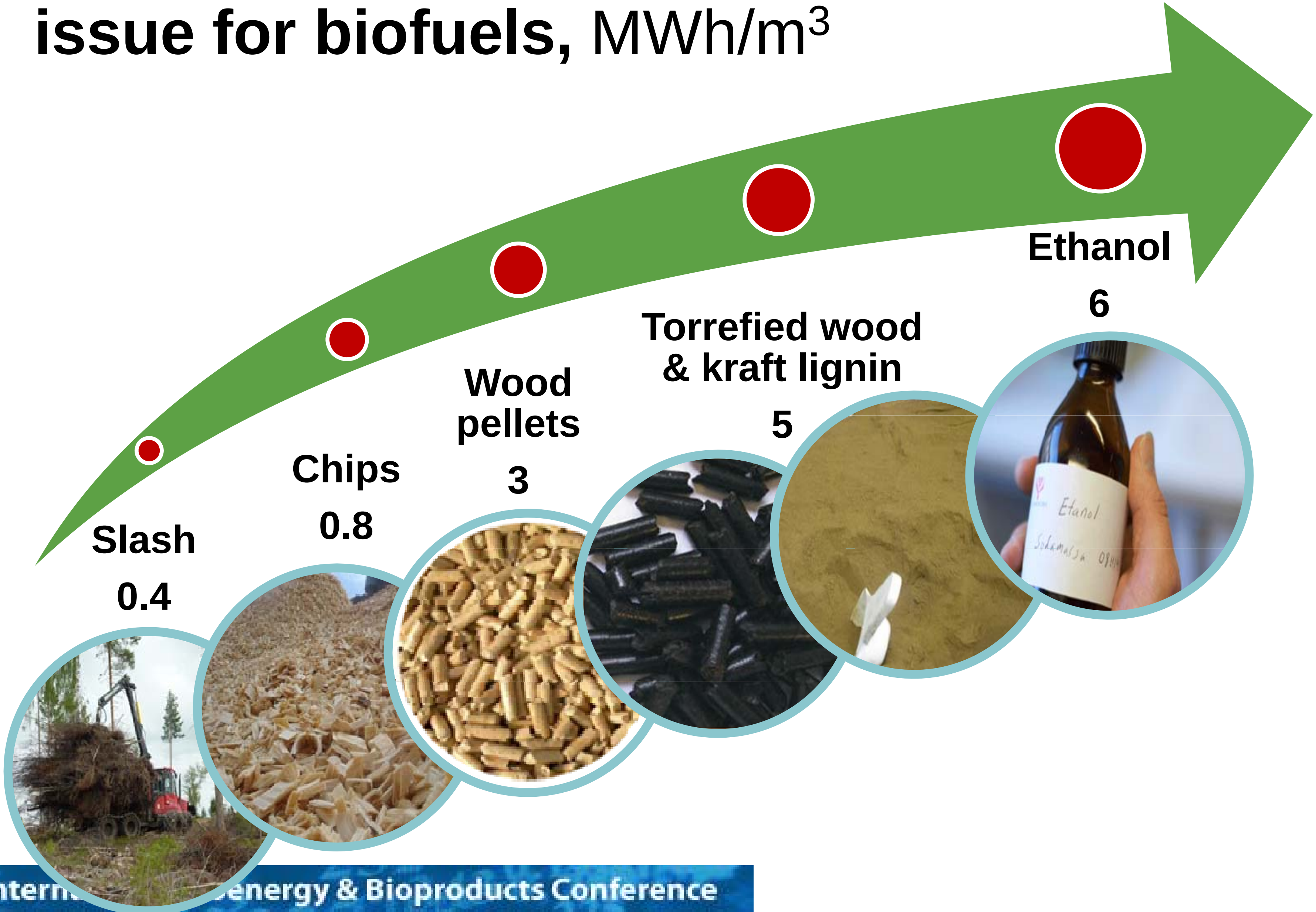
LignoBoost kraft lignin fuel characteristics

		Lignin	Coal	Wood chips	Bark pellets
Moisture	%	30-40	9	50	10,3
Ash	%	0,02-1	11,7	2-3	3,6
HHV	MJ/kg	26-27	29,8	20	21
LHV	MJ/kg	17-19	25,9	7,7	17,7
Sulphur, S	% db	2-3	0,4	0,05	0,04
Chloride, Cl	%	<0,01	0,04	0,03	0,02
Bulk density	kg/m3	500-600***	800	200-300	550-700

***Moist filter cakes. Dry lignin powder has a bulkdensity of 630-720 kg/m^3

Energy density is a key issue for biofuels, MWh/m^3

TAPPI people resources solutions



Successful energy applications tested by Innventia

- Lime kiln
- Co-firing with bio-fuels
- Co-firing with coal
- Kraft lignin pellets (100%) & additive (1-10%) in fuel pellets
- Kraft lignin powder suspended in oils

Full scale trial with kraft lignin as fuel in a lime kiln at the Södra Cell Mönsterås pulp mill

- April 15-17, 2008
- 275 tpd lime kiln
- 37 tonnes fired
- 32 hours
- 50 - 100 % oil replacement

Reference: Tappi Int .Chem. Rec. Conf. 2010, Williamsburg, USA

Kraft lignin fuel in lime kilns

Summary

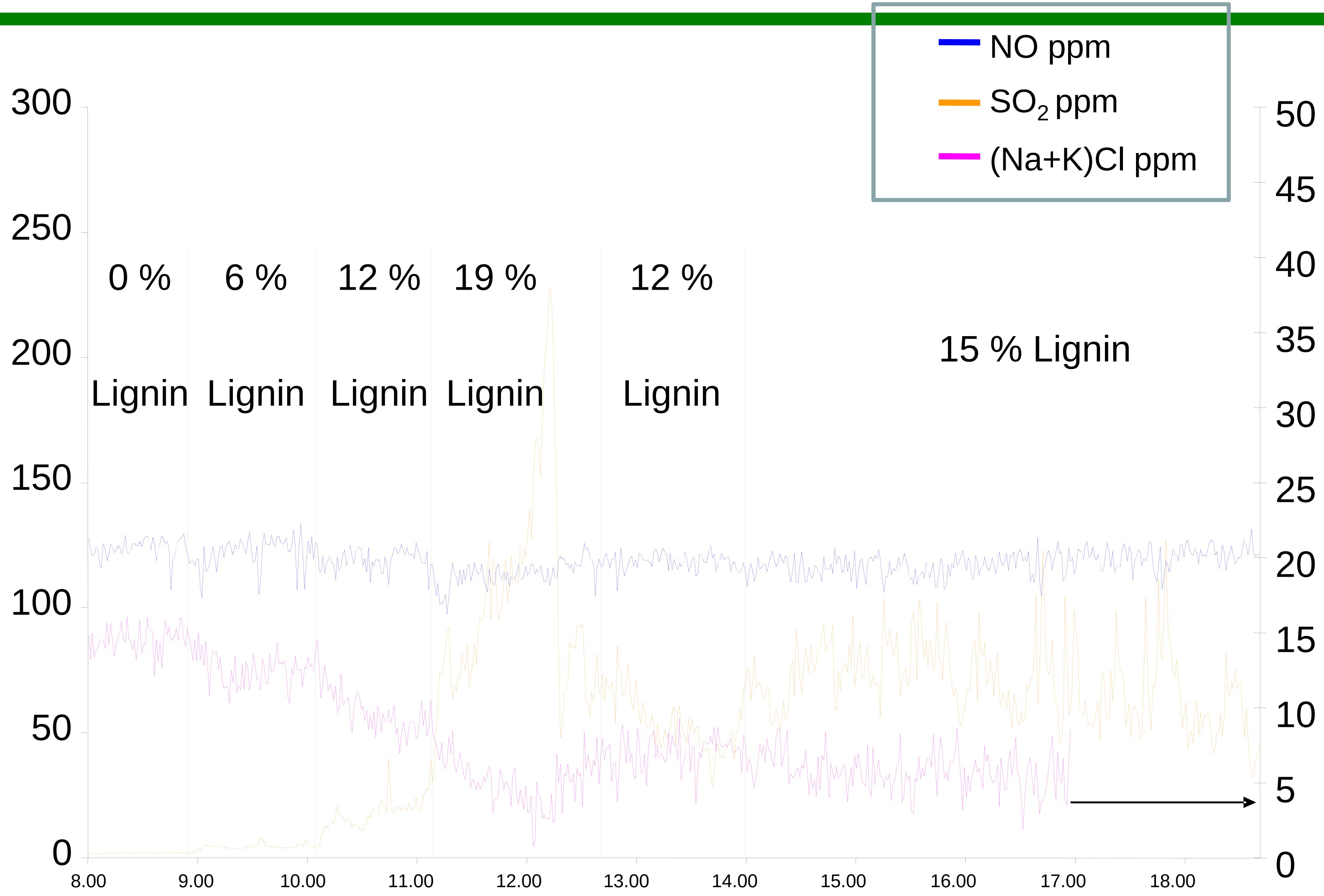
- Stable and continuous operation of a lime kiln when lignin is used as fuel.
- Standard powder burners and feeding equipment when firing lignin - OK.
- No sign of lignin stuck at the burner or in supply pipe system.
- The temperature levels in the kiln are of the same order of magnitude when firing lignin as when firing oil or wood powder.
- OK to keep the O_2–level at normal values at the combustion of lignin, i.e. same as during bark and oil firing.
- Lime quality: not effected
- Increased SO_2 emission between 85-100% (kiln specific level?)

Co-firing of kraft lignin & bark in a CFB

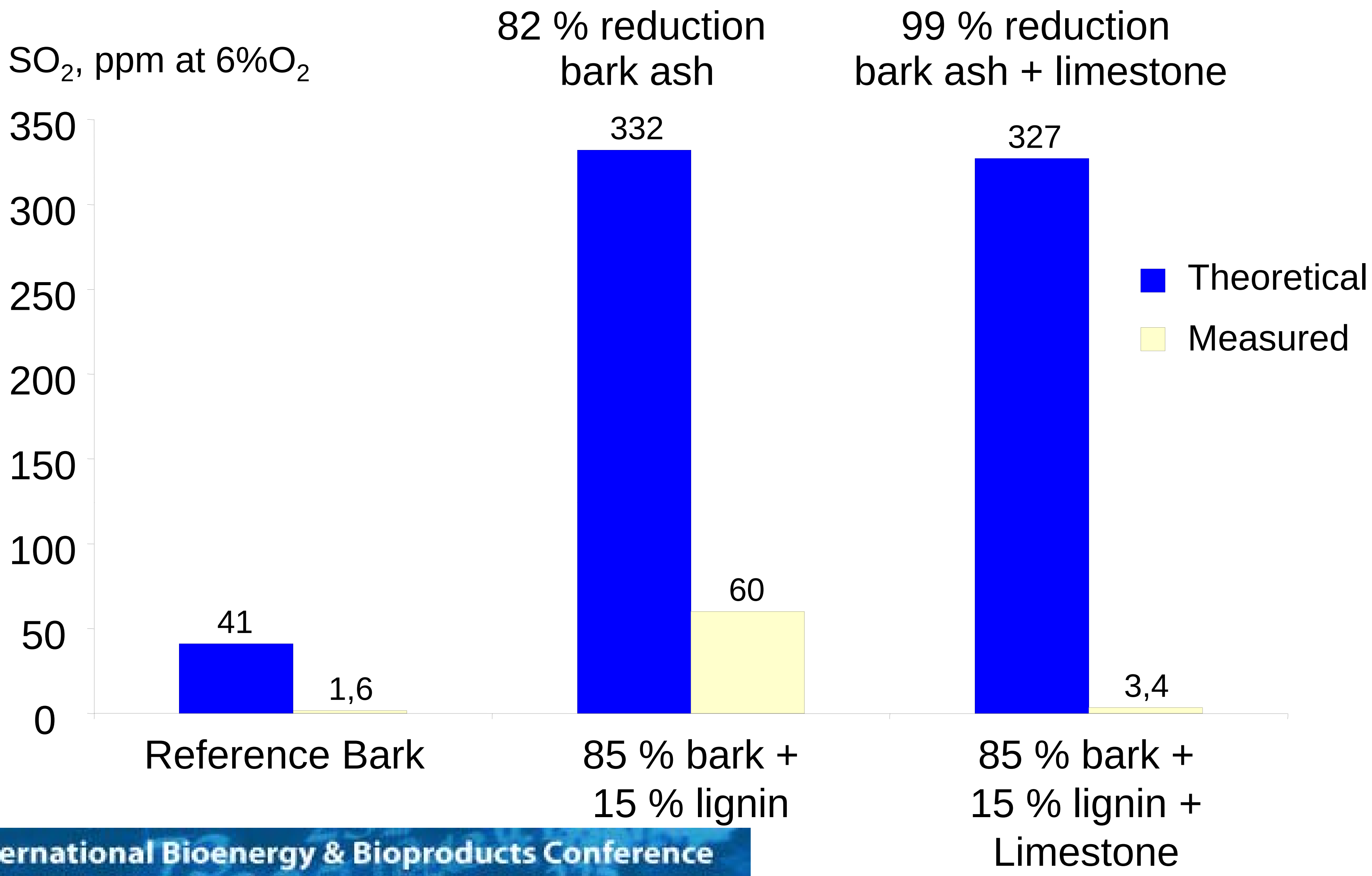
- Co-firing of lignin and bark in a12 MW research CFB-boiler at Chalmers University of Technology
- 3 tonnes of the lignin limited the trial to 3-days.
- The objectives were to study:
  - Fuel feeding properties in Chalmers feeding system
  - Effects on combustion conditions (CO, NOx, temp, etc)
  - SO_2-emissions
  - SO_2-reduction with limestone addition
  - Deposits on tubes
  - Effects on sintering properties of the bed material

Reference: Tappi Engineering, Pulping & Environmental Conf., Portland, Oregon, Aug 25-27, 2008

Co-firing of kraft lignin and bark



SO_2 capture by bark ash and limestone addition



Co-firing in a CFB

Full scale

April 2010

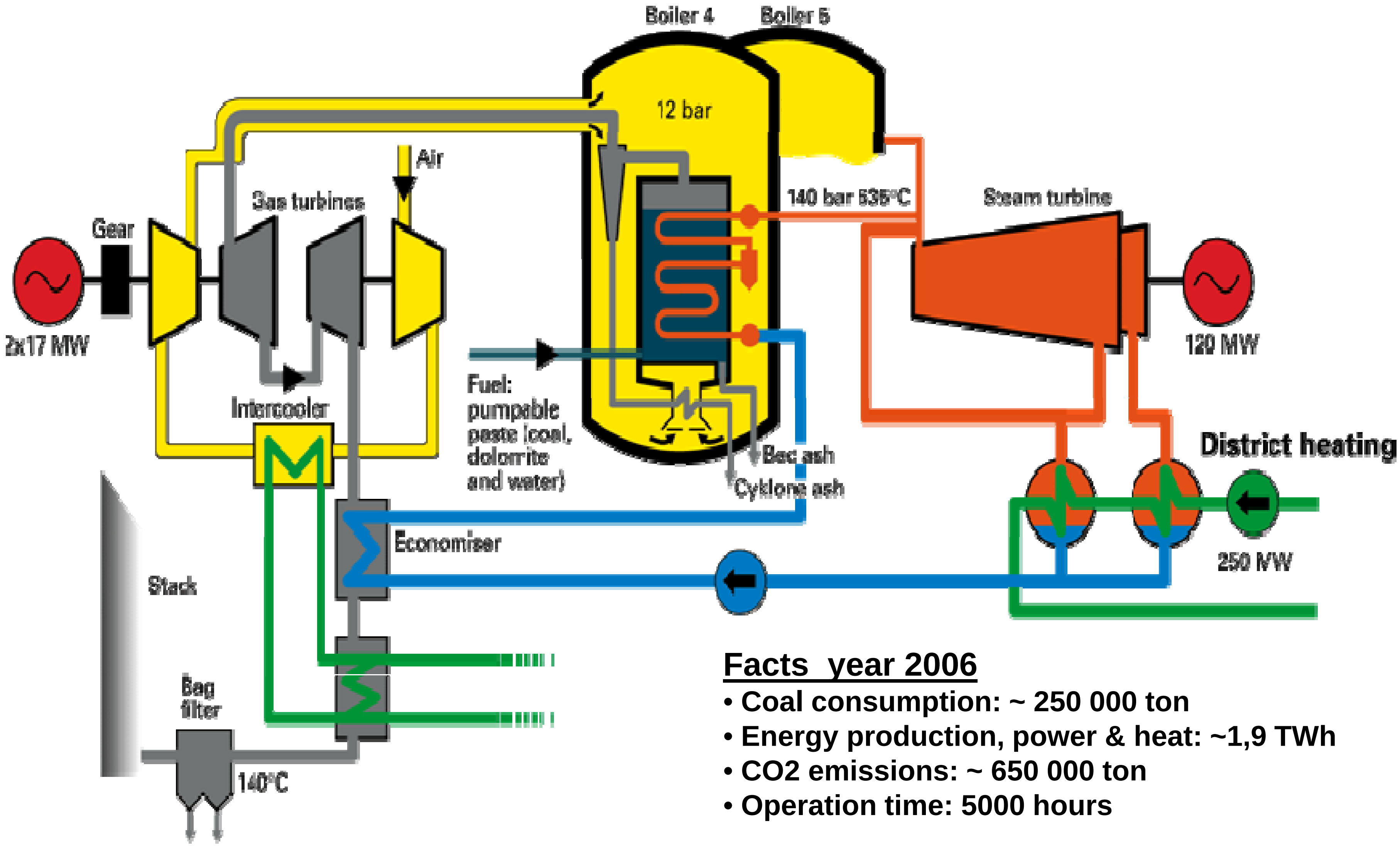
Co-firing in a CFB

Summary

- Feeding works well without any clogging problems
- A stable and continuous combustion is fully possible
- Sulphur content in kraft lignin can be used to reduce the alkali choride content in the deposits, thus reducing the risk for sticky deposits and high temperature corrosion
- Calcium in bark ash captured sulphur.
- Conventional sulphur capture with addition of limestone to the bed was also demonstrated.
- Kraft lignin addition had no measureble effect on the sintering properties of the bed material

Coal fired PFBC plant in Stockholm (Värtaverket)

(Pressurised Fluidised Bed Combined Cycle)



Facts year 2006

- Coal consumption: ~ 250 000 ton
- Energy production, power & heat: ~1,9 TWh
- CO2 emissions: ~ 650 000 ton
- Operation time: 5000 hours

Co-firing coal and kraft lignin

Demonstration scope

- Kraft lignin transported 300 km by trucks (40 ton lignin/truck) from the LignoBoost demo plant to Stockholm.

- The lignin was intermediate stored up to a year in 10 ton containers. No problems with biological activity or degradation.

- 4 000 ton of lignin 60 % DS (24 GWh) was co-fired with coal during 4 campaigns - totally 13 weeks (8 weeks continuous operation). The energy mix of lignin was 2 -15 %.

- Kraft lignin was added to coal, dolomite and water. This paste was pumped 300 m to the PFBC and injected with existing six burners

Results co-firing coal & kraft lignin

- The fuel injection into the boiler and fluidized bed worked well and the distribution of fuel in the bed was very good.

- Compared to coal firing the centre of combustion shifted downwards due to the high reactivity of the lignin.

- No appeared changes in NO_x, N_2O, CO and HCl emissions were observed. The sulphur emission increased from 1-3 mgS/MJ to 12-13 mgS/MJ when co-firing with 15 % lignin (energy basis)

- Fortum Värme expect at least 30% coal substitution with optimal designed equipment.

Reference: Bioenergy 2009, Jyväskylä, Finland, 31 Aug- 4 Sept, 2009

Pellets, 100 % kraft lignin

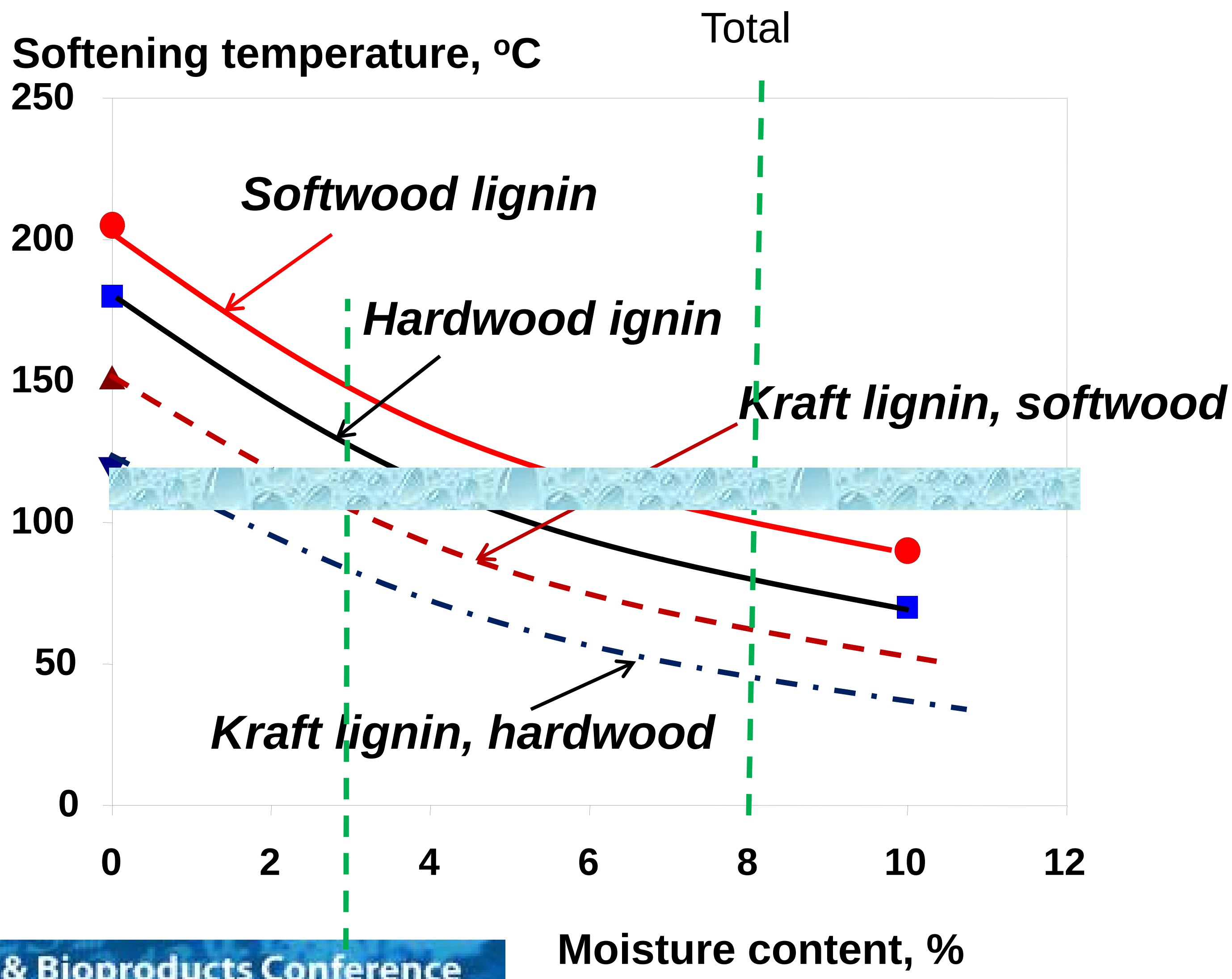
Small and large scale pilot units from Amandus Kahl

10-100 kg scale

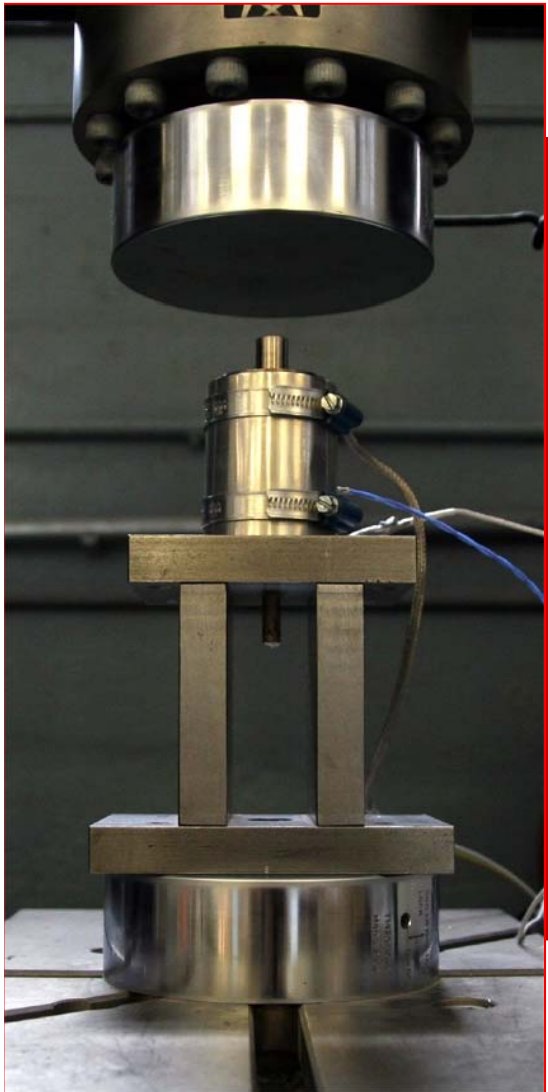
100-1000 kg scale

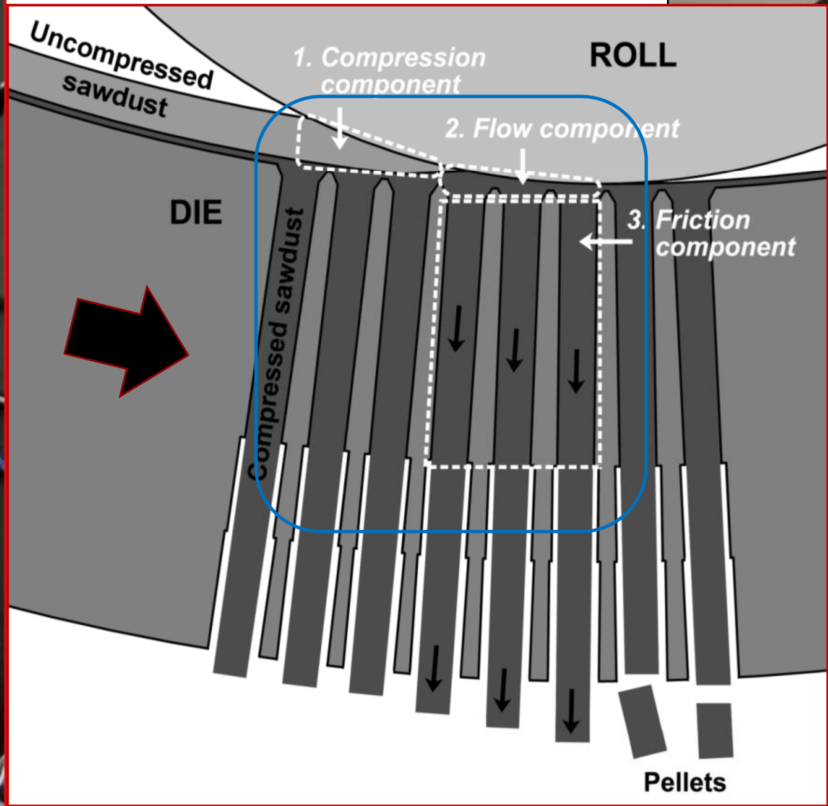
Kraft lignin as additive

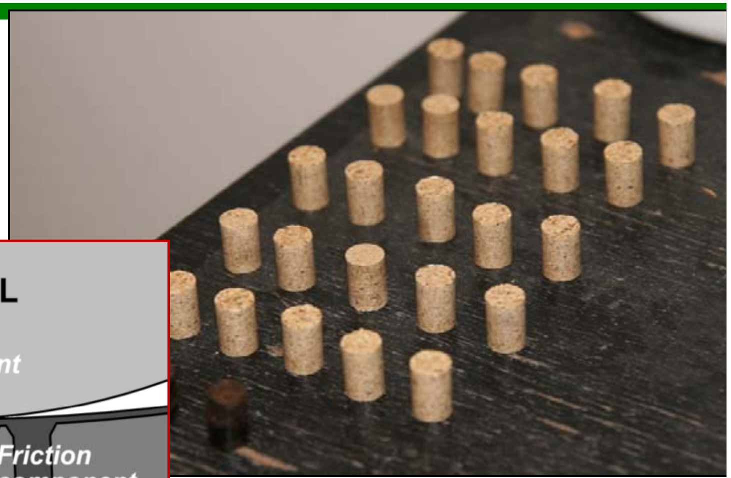
- we use the softening properties

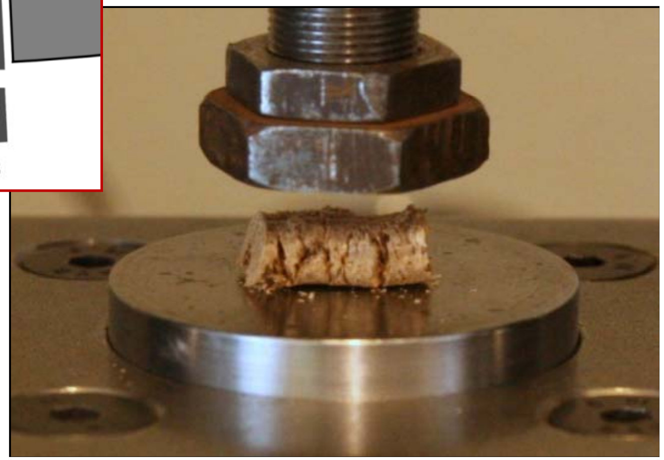


Evaluation by single pellet pressings









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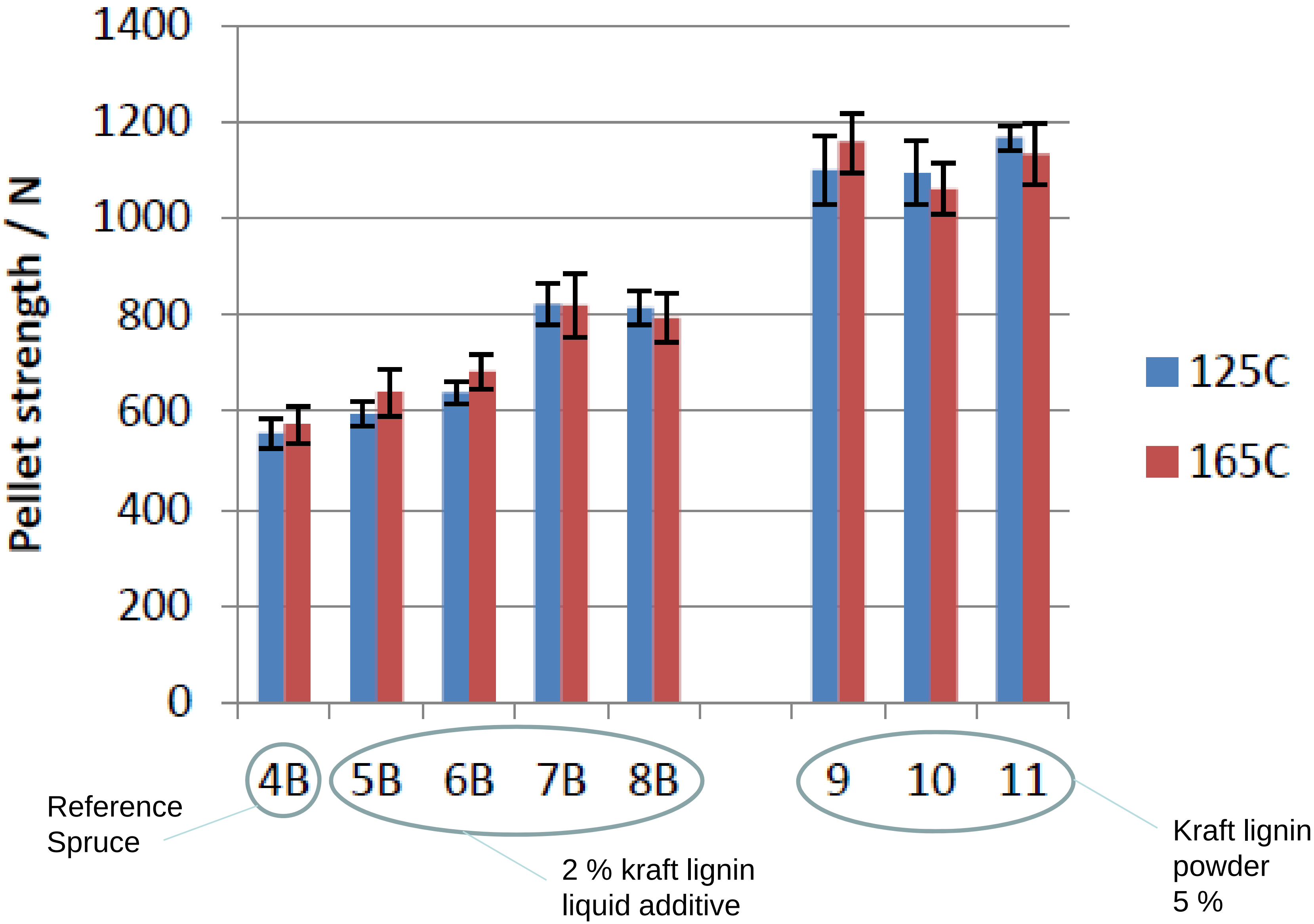
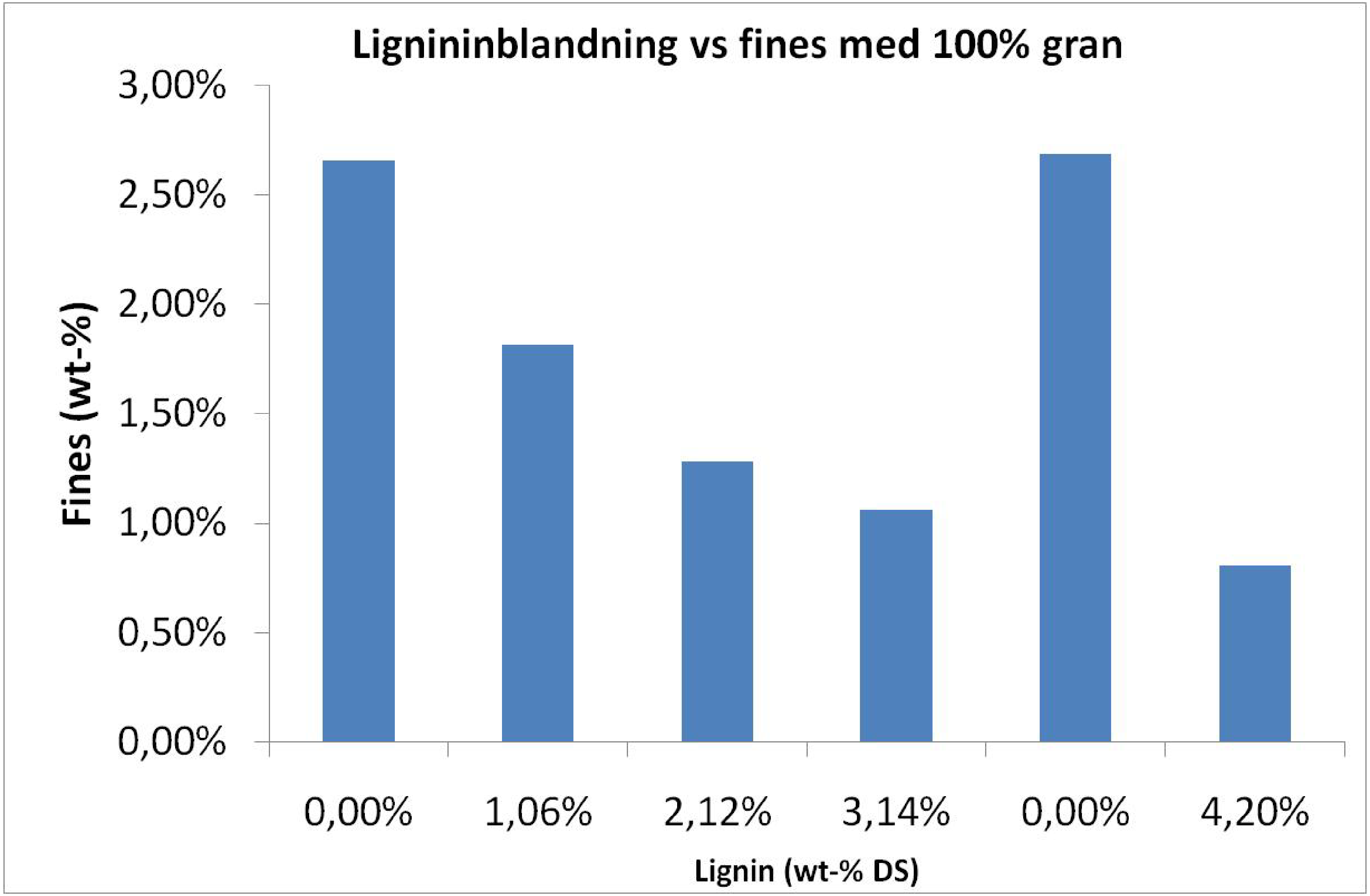


Pilot scale - pelletizing of fresh spruce



Kraft lignin pellets & kraft lignin as additive

Summary

- Lignin can be pelletized when needed.
  - Normal energy input is needed
  - Correct handling system is important
- Moisture is an important softening agent
- Addition of lignin to biofuel pellets improves the strength and energy density
- Lignin is hydrophobic – pellets have good water resistance properties. Also other good storage properties

LignoBoost lignin mixed with fuel oil

30-50 % lignin (energy-%) in fossil fuel oil 5

We have also sucessfully mixed lignin with liquid bio-fuels like tall oil, tall oil pitch & glycerine from bio-diesel production

Summary

- Secure a continuous bulk production & use of lignin
- Substitute fossil fuel oil - sets the lignin value & should include potential green credits
- Do not forget applications where washed, moist lignin is accepted.
- Next generation applications: carbon fibers, etc

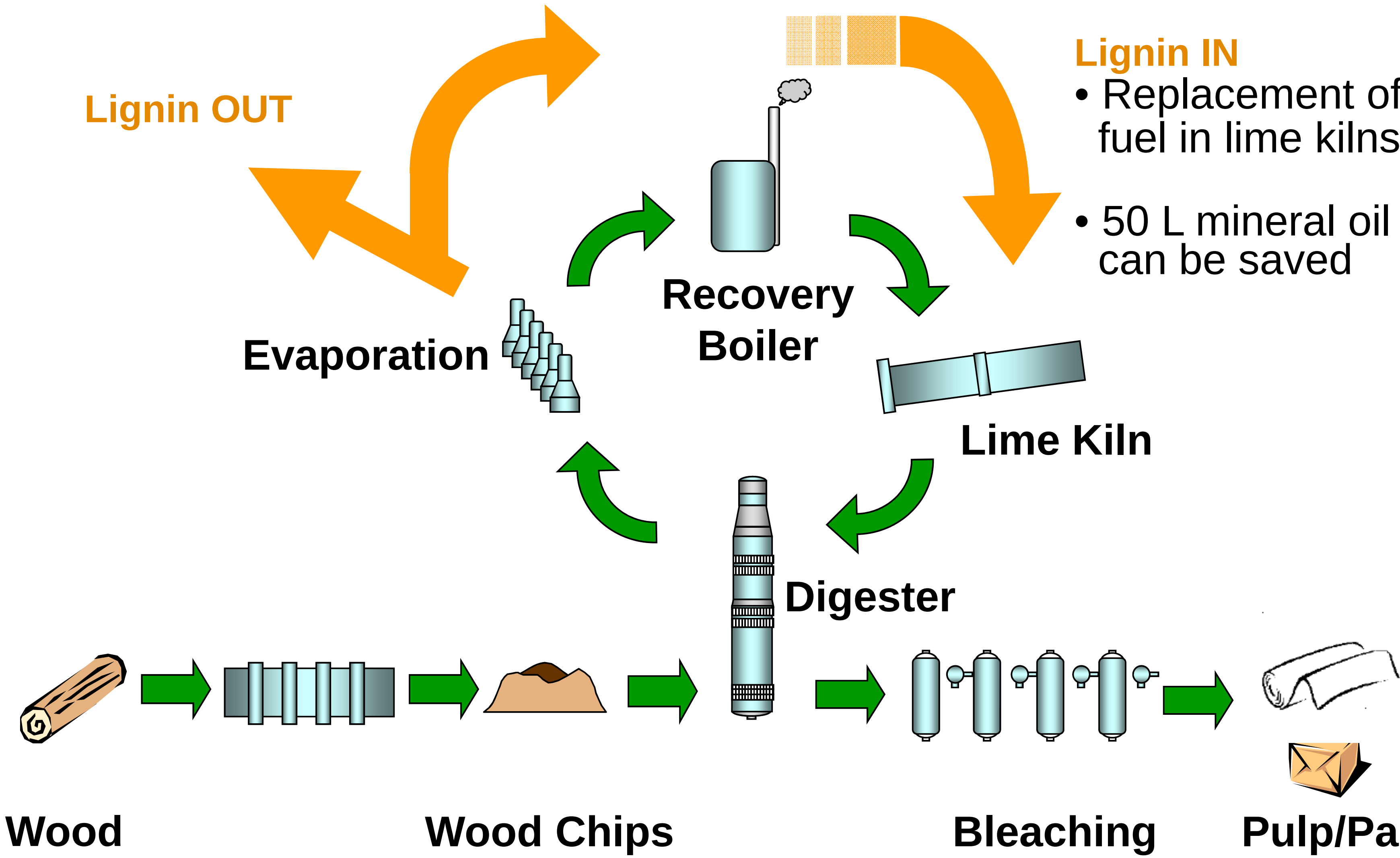
Successful demonstrations (a short term perspective):

- Moist lignin cakes co-combusted with bio-fuels (bark)
- Moist lignin cakes co-combusted with coal
- Moist lignin as additive in biofuel pellets (wood, straw etc)
- Dry lignin powder fuel in lime kilns/cement kilns
- Lignin pellets or new combinations
- Lignin slurries with fuel oil, tall oil, tall oil pitch, glycerine etc

Kraft Lignin Impregnated Pulp Fibres

Thank you for your attention!

Lignin removal

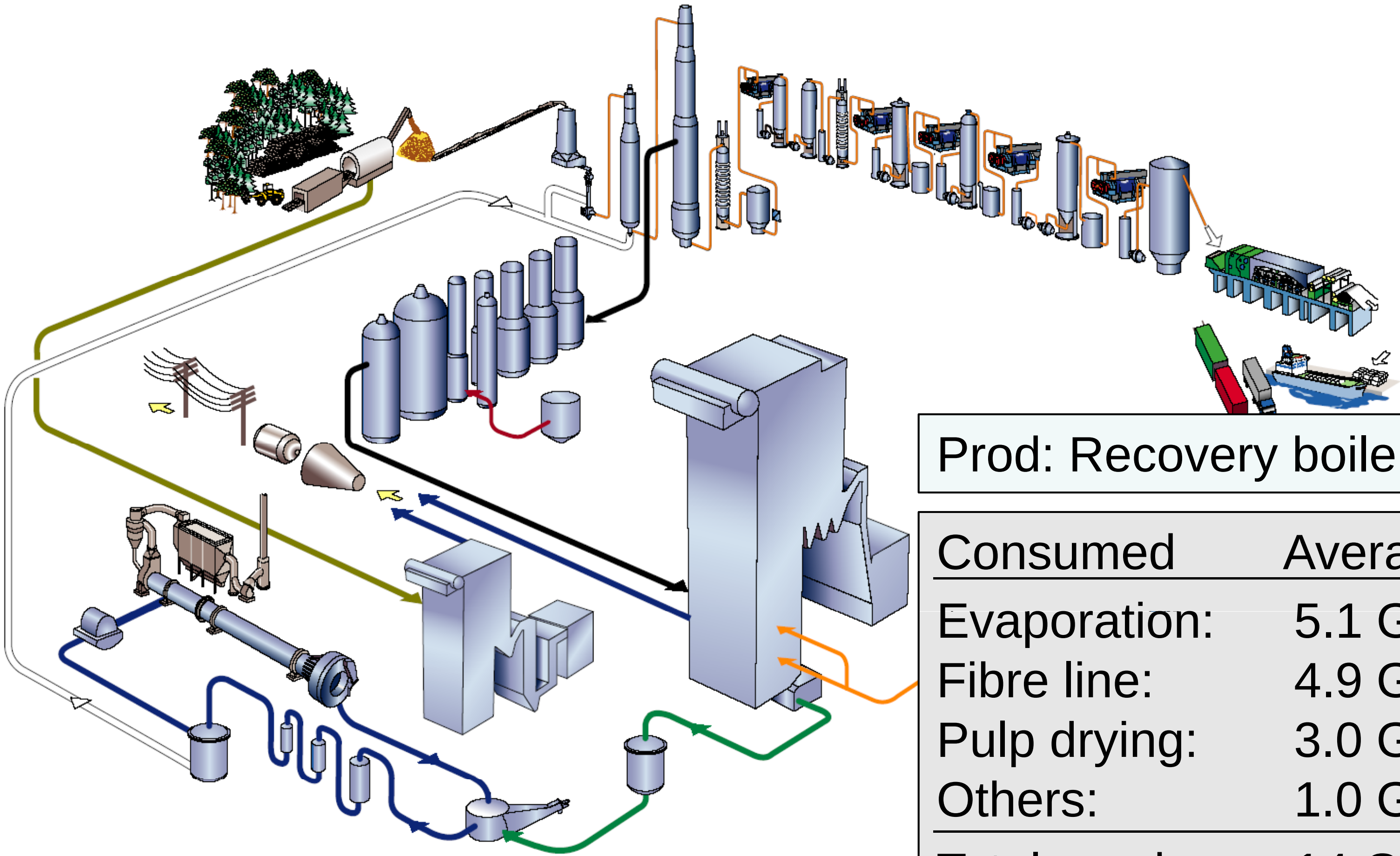


- Replacement of fossil fuel in lime kilns
- 50 L mineral oil ptp can be saved

Biorefinery activities at Innventia

Energy situation in a pulp mill

Summary: General steam balance (2003)



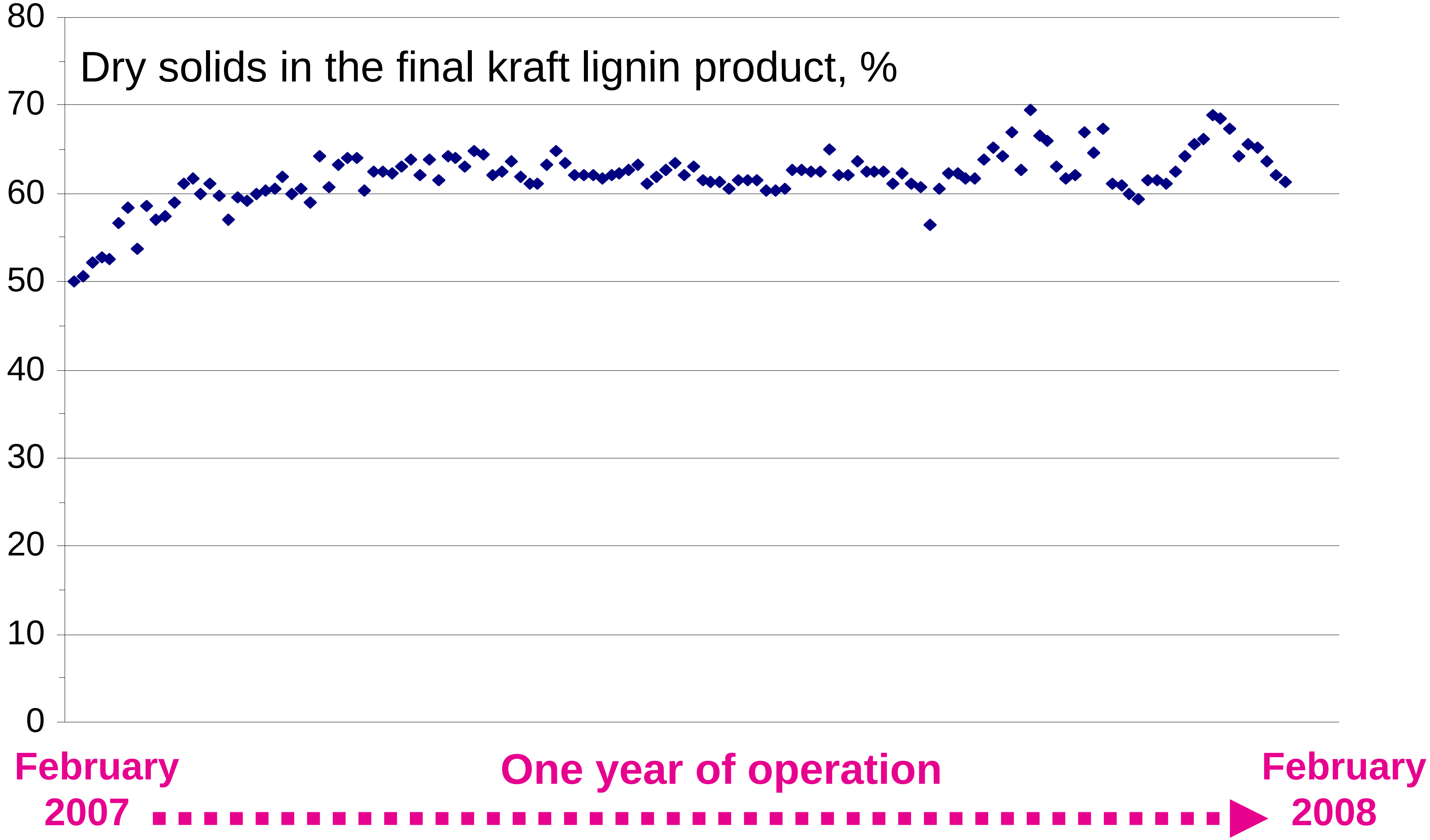
Prod: Recovery boiler: 15.2 GJ/ADT

Consumed	Average mill	BAT
Evaporation:	5.1 GJ/ADT	4.0
Fibre line:	4.9 GJ/ADT	3.2
Pulp drying:	3.0 GJ/ADT	2.2
Others:	1.0 GJ/ADT	0.0
Total need:	14 GJ/ADT	10.8

Reference: Johansson, M., "Heat transfer and Hydrodynamics in Falling film Evaporation of Black Liquor", Chalmers University of Technology, 2008. KAM, report A100, 2003

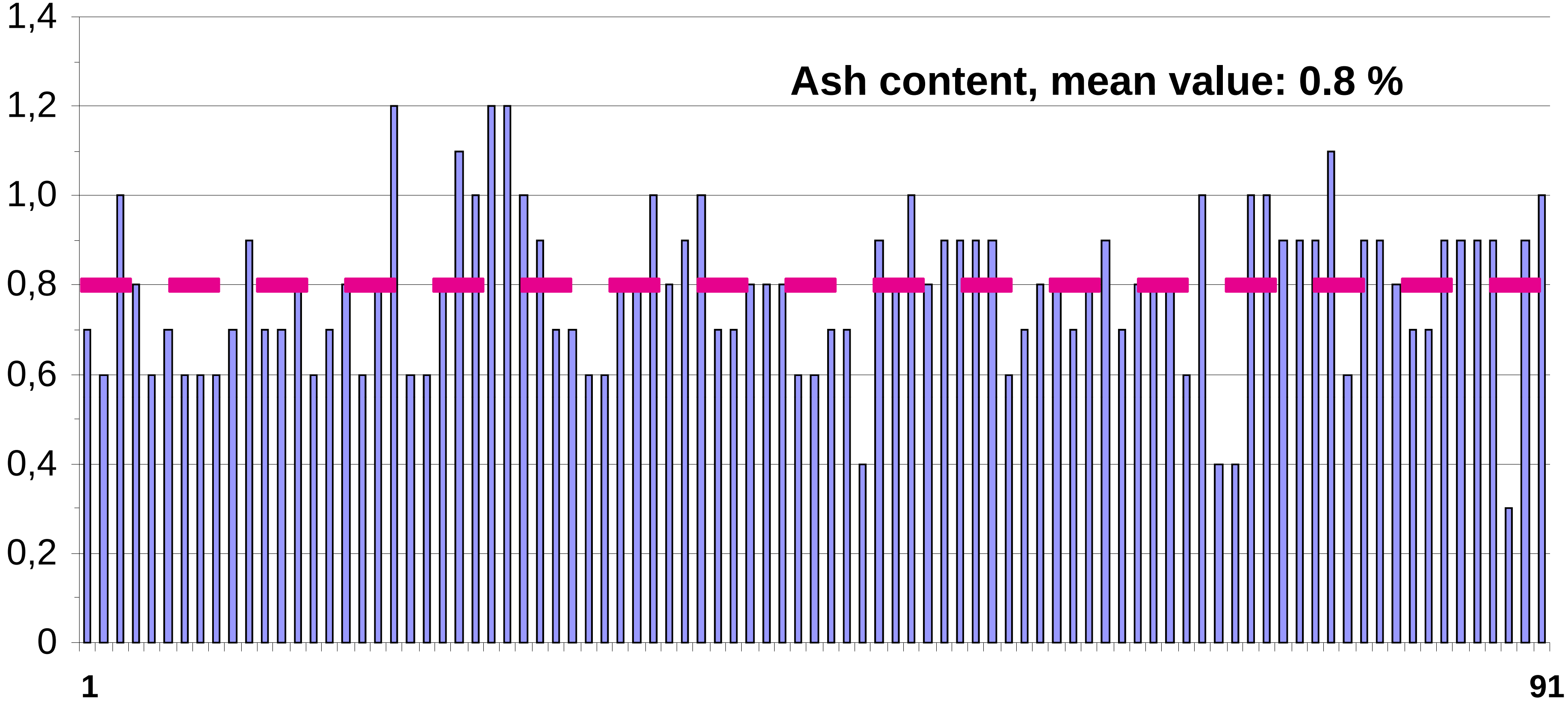
LignoBoost Demonstration plant

Samples from the first year of operation



LignoBoost Demonstration plant

Ash content in the final kraft lignin product, %

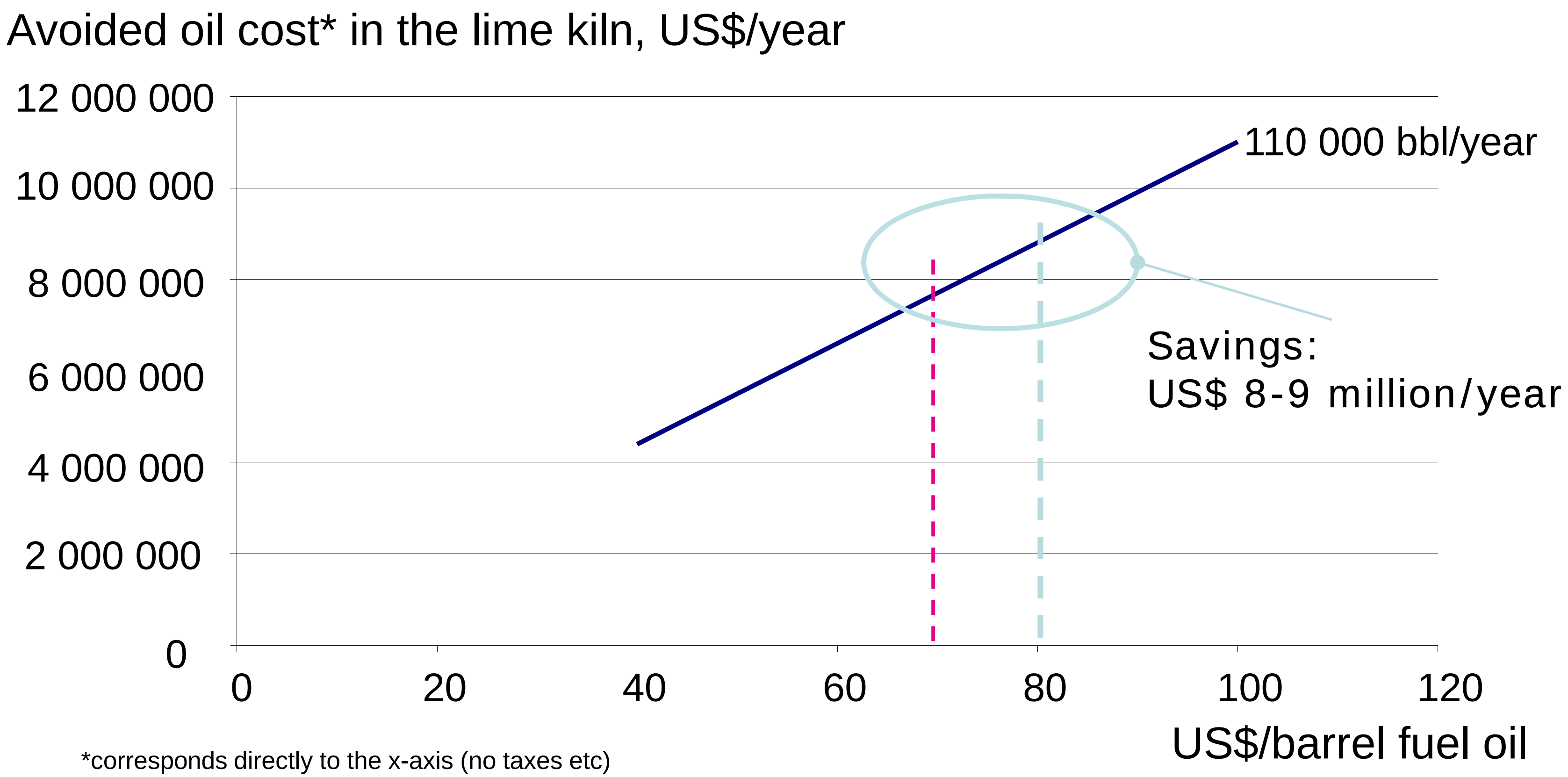


Sample	Example		Median	Range		No
				Min	*Max*	
Fuel content (weight-%)						
Moisture	29,3		32,3	29,3	40,0	3
Ash(dry)	1,4		1,0	0,2	1,4	5
Heat value (MJ/kg)						
HHV (dry ashfree)	26,7		27,1	26,6	27,3	5
HHV (moist)*	18,6		18,2	15,9	18,6	3
LHV (dry ashfree)	25,4		25,9	25,3	26,0	5
LHV (moist)*	16,9		16,6	14,2	16,9	3
Elementary analysis (% dry ashfree)						
C (carbon)	63,6		65,1	63,6	66,2	5
H (hydrogen)	6,2		5,8	5,7	6,2	5
O (oxygen)	27,5		26,1	25,9	27,5	5
S (sulphur)	2,54		2,5	1,8	3,2	5
N (nitrogen)	0,15		0,1	0,1	0,2	5
Cl (chlorine)	0,01		0,01	0,01	0,01	2
Ash analysis						
	mg/kg DS	***mg/kg ash***	***mg/kg ash***			
Al (aluminum)	364	26 000	17 824	7 857	34 500	4
As (arsenik)			15	14	16	2
Ba (barium)	31	2 200	2 000	499	2 200	3
Ca (calcium)	1 085	77 500	4 037	2 000	77 500	4
Cd (cadmium)			10	9	11	2
Co (cobolt)			10	8	11	2
Cr (chromium)			257	108	500	3
Cu (cupper)			157	59	800	3
Fe (iron)	270	19 300	4 036	1 250	19 300	3
Hg (mercury)			2	1	4	2
K (potassium)	543	38 800	38 800	24 000	76 154	5
Mg (magnesium)	116	8 300	1 996	1 700	8 300	3
Mn (manganese)	71	5 100	2 835	900	5 100	3
Mo (molybdenium)			484	353	614	2
Na (sodium)	1 666	119 000	151 500	119 000	227 152	5
Ni (nickel))			69	59	79	2
P (phosphorous)	66	4 700	2 484	269	4 700	2
Pb (lead)			16	11	21	2
Sb (antimony)						
Si (silica)	979	69 900	13 071	10 536	69 900	4
Ti (titanium)	25	1 800	969	138	1 800	2
Tl (thallium)					0	
V (vanadium)			820	769	871	2
Zn (zinc)			500	443	954	3

One driving force to avoid fossil fuels in lime kilns

Use of 50 liter oil (13.2 gallon) in the lime kiln/ADt pulp

Example: **In a pulp mill producing 350 000 ADt/year, without a production increase:**
- means 110 000 bbl / year (17 500 m3 / year)
- corresponds to 25 000 tonnes of lignin on energy basis



*corresponds directly to the x-axis (no taxes etc)

LignoBoost equipment and installation

Typical installation

- 2 or 3 VPA pressure filters
- Precipitation equipment
  - CO_2 storage tanks – optional
- Process pumps and tanks
- Piping and valves
- Heat exchangers
- Scrubber, vacuum pump and fan
- Belt conveyors