Cofiring in large scale CFB - Experience gained from experiments with the world's largest biofuel fired CFB of Alholmens Kraft, Finland

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2nd World Conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection

FP5 Project partners

”Maximum biomass use and efficiency in large-scale co-firing” (BIOMAX)

VTT Processes, Finland

Alholmens Kraft, Finland

Kvaerner Power, Finland

CIRCE Foundation, Spain

Elsam Engineering, Denmark

Abo Akademi University, Finland

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- Alholmens Kraft CHP plant – general features
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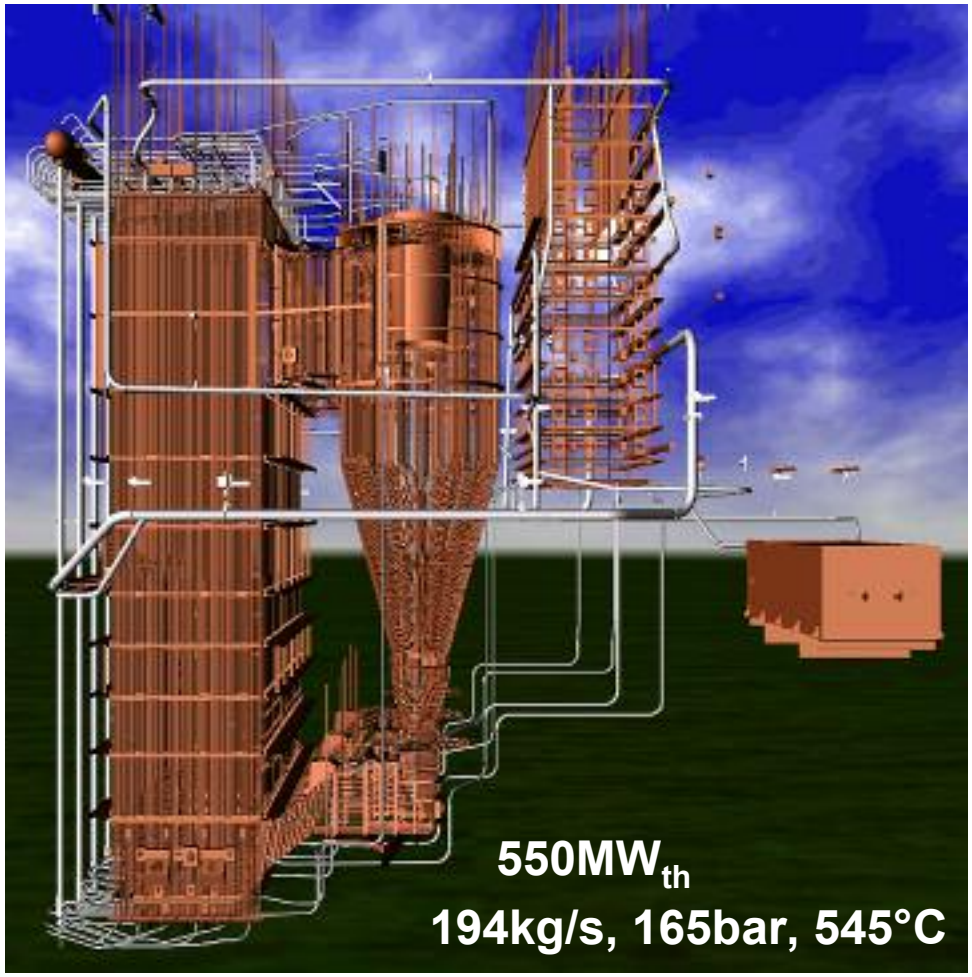
- Means to avoid chlorine deposition
  - Protective elements
  - Protective elements from fuel blending

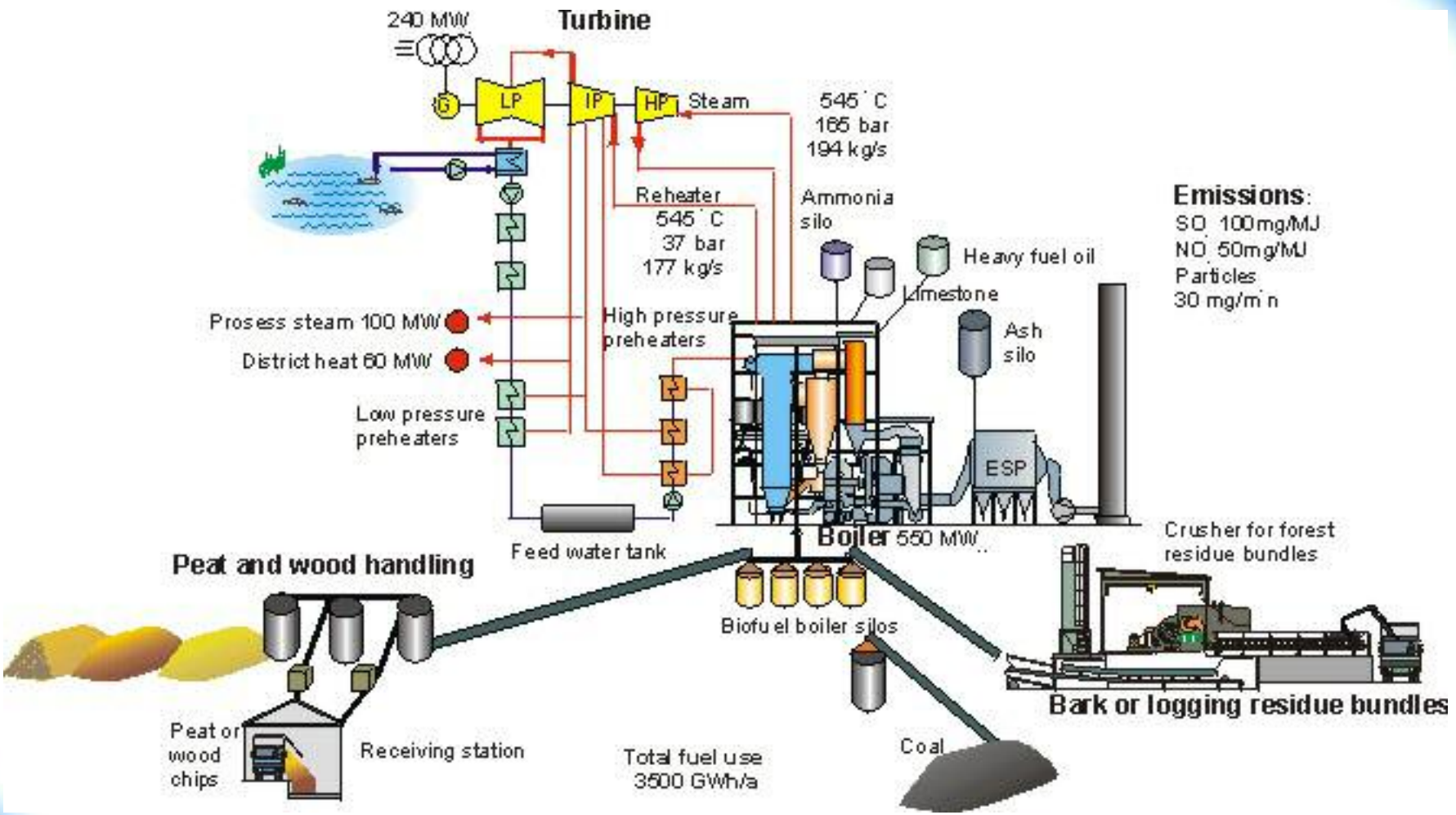
Source:
Kvaerner Power Oy

The boiler



- Annual proportion of fuels:
  - Peat 50%
  - Wood fuels 25% (LR, Bark)
  - Coal 25%
- 2.5 years of successful operation in open electricity market
- Operates with anything from 100% coal to 100% biofuel
- Combusts the fuels in any given combination while staying within the emission limits
- Consumes a truck load of peat in 7 minutes
- 30,000 truck deliveries annually
- Furnace measures 8.5m by 24m and is 40m in height

The Process


240 MW
Turbine
G
LP
IP
HP
Steam
545 °C
165 bar
194 kg/s
Reheater
545 °C
37 bar
177 kg/s
Ammonia silo
Heavy fuel oil
Limestone
Emissions:
SO2 100mg/MJ
NOx 50mg/MJ
Particles
30 mg/m3n
Prosess steam 100 MW
District heat 60 MW
High pressure preheaters
Ash silo
Low pressure preheaters
ESP
Feed water tank
Boiler 550 MW
Crusher for forest residue bundles
Peat and wood handling
Biofuel boiler silos
Bark or logging residue bundles
Peat or wood chips
Receiving station
Total fuel use 3500 GWh/a
Coal

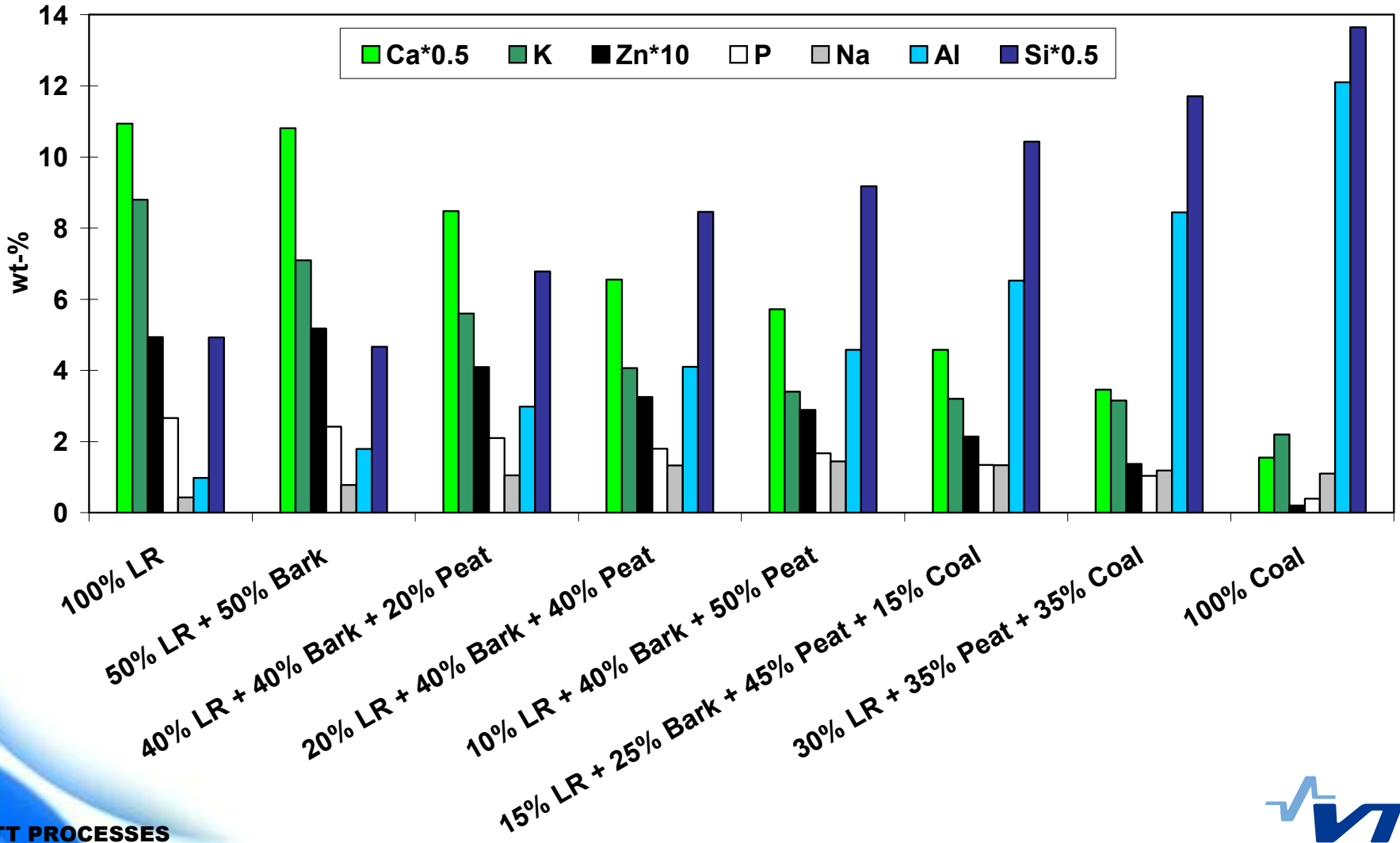
The experiment matrix

	Peat	*Coal*	*Bark*	*Logging residue*	*Wood chips*	*Lime*
1	57	43	-	-	-	-
2	95	5	-	-	-	-
3	26	50	-	24	-	-
4	-	56	44	-	-	-
5	50	-	25	25	-	-
6	43	24	33	-	-	-
7	61	-	39	-	-	-
8	63	-	-	37	-	-
9	-	-	-	100	-	-
10	-	10	-	90	-	-
11	-	-	40	-	60	-
12	-	10	42	-	48	-
13	49	25	26	-	-	-
14	47	25	28	-	-	X
15	18	50	32	-	-	X
16	18	50	32	-	-	X

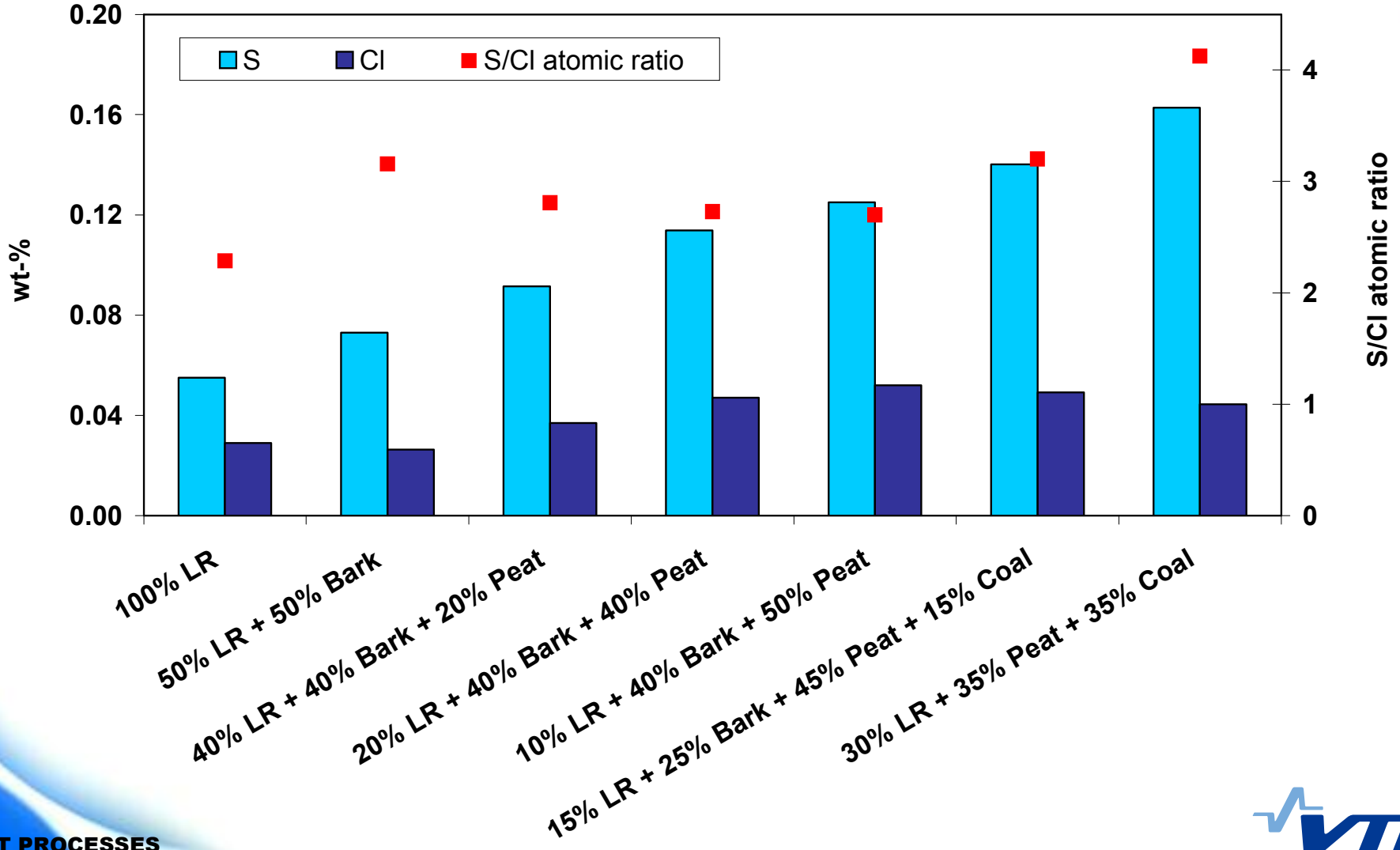
Fuel properties

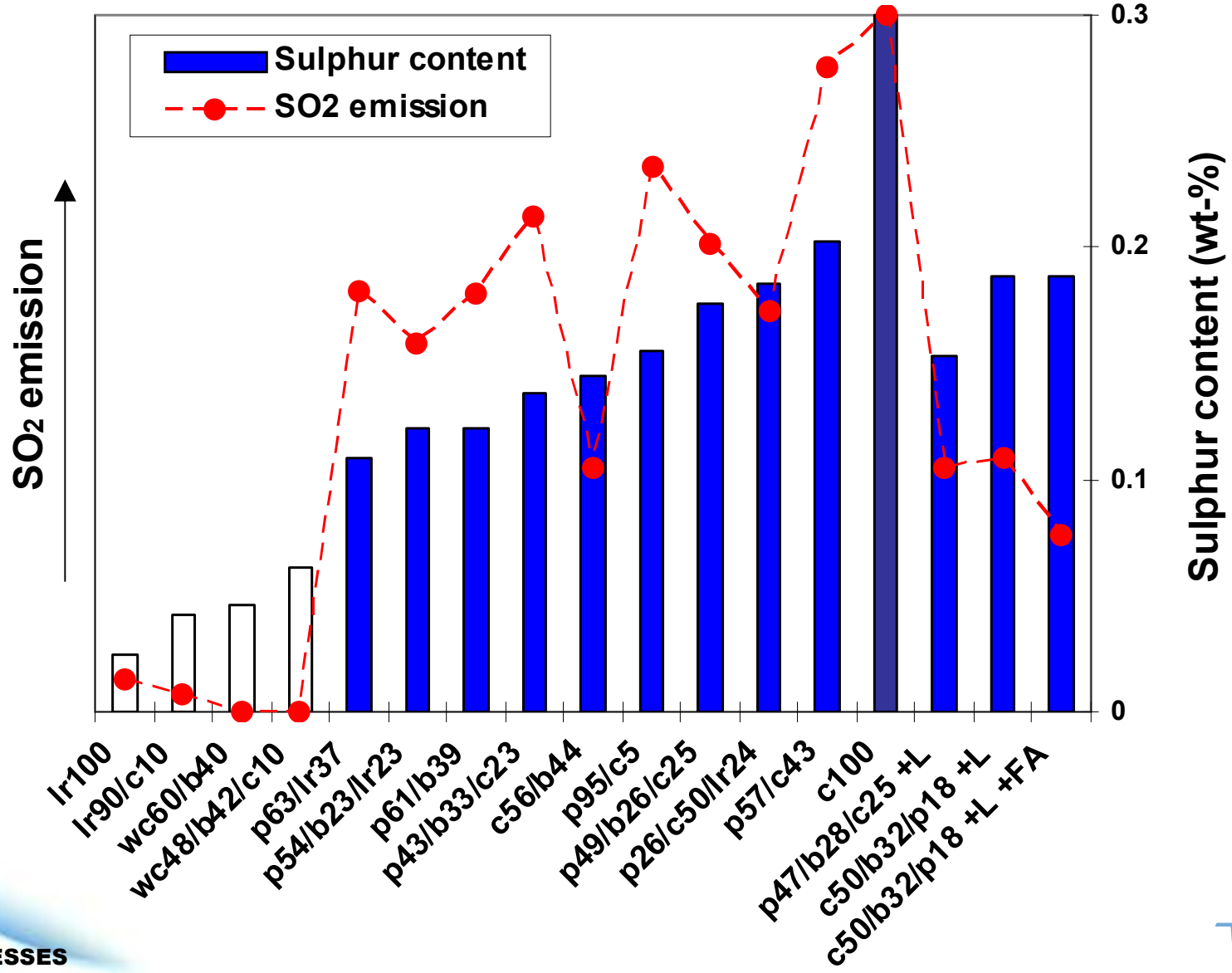
FUELS	Peat	Coal	Bark	LR	WC
Total moisture	41.8	12	48-52	40-52	41.7
Ash (wt-%, D.S.)	6.8	12	2.5	2.5	3.3
ULTIMATE ANALYSIS OF DRY SOLIDS (wt-%)					
C	53.1	73.0	51.0	50.0	55.0
H	5.2	4.5	5.6	6.0	5.8
N	1.5	2	0.7	0.4	1.5
O	33.3	8.2	40.2	41.0	34.4
S	0.15	0.3	0.04	0.06	0.014
Cl	0.020	0.010	0.010	0.014	0.004
HEATING VALUE (MJ/kg)					
HHV	20.5	27.0	21.9	21.1	19.6
LHV	10.9	22.5	9.2	8.1-10.2	9.6

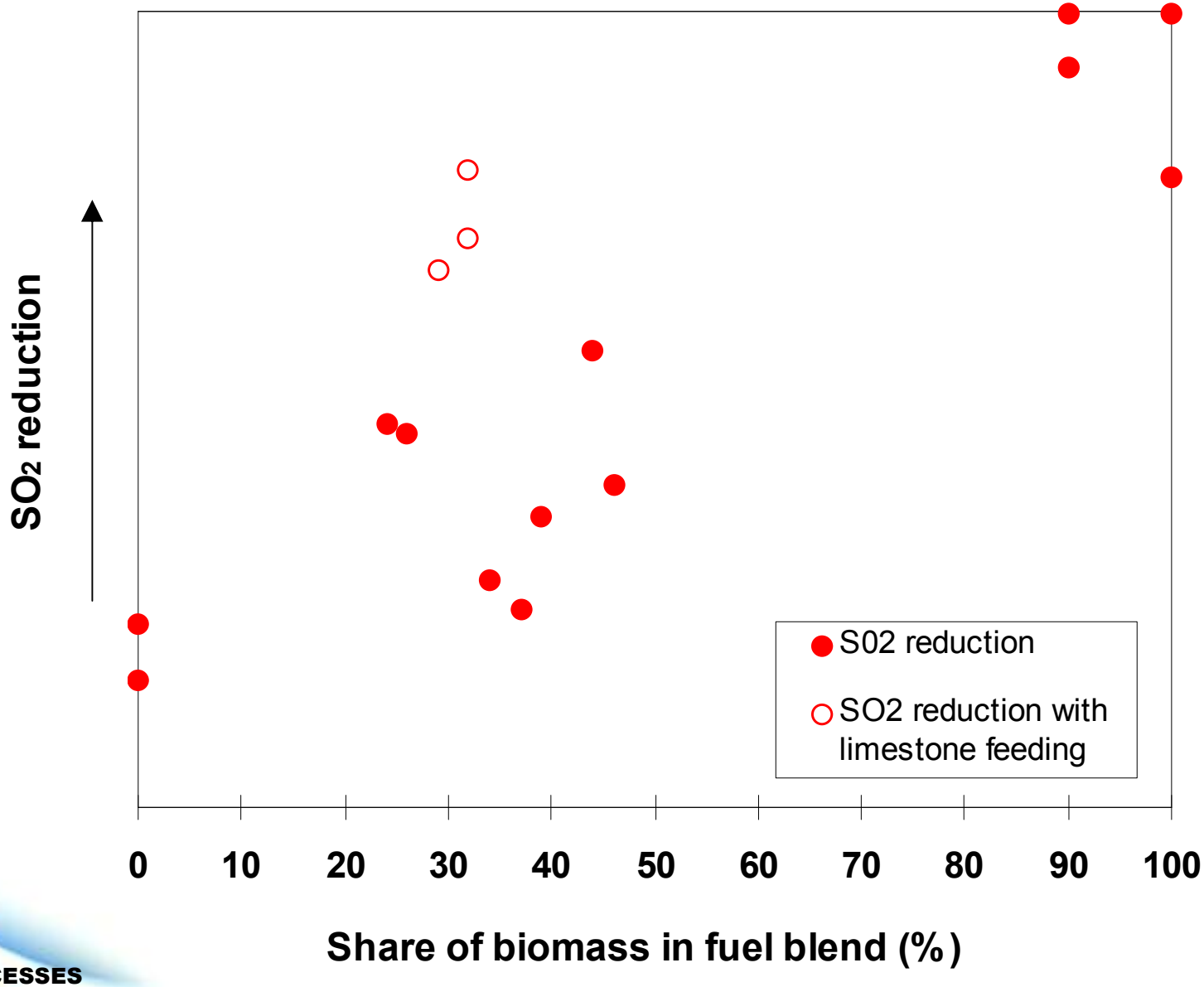
Sources of contributing elements



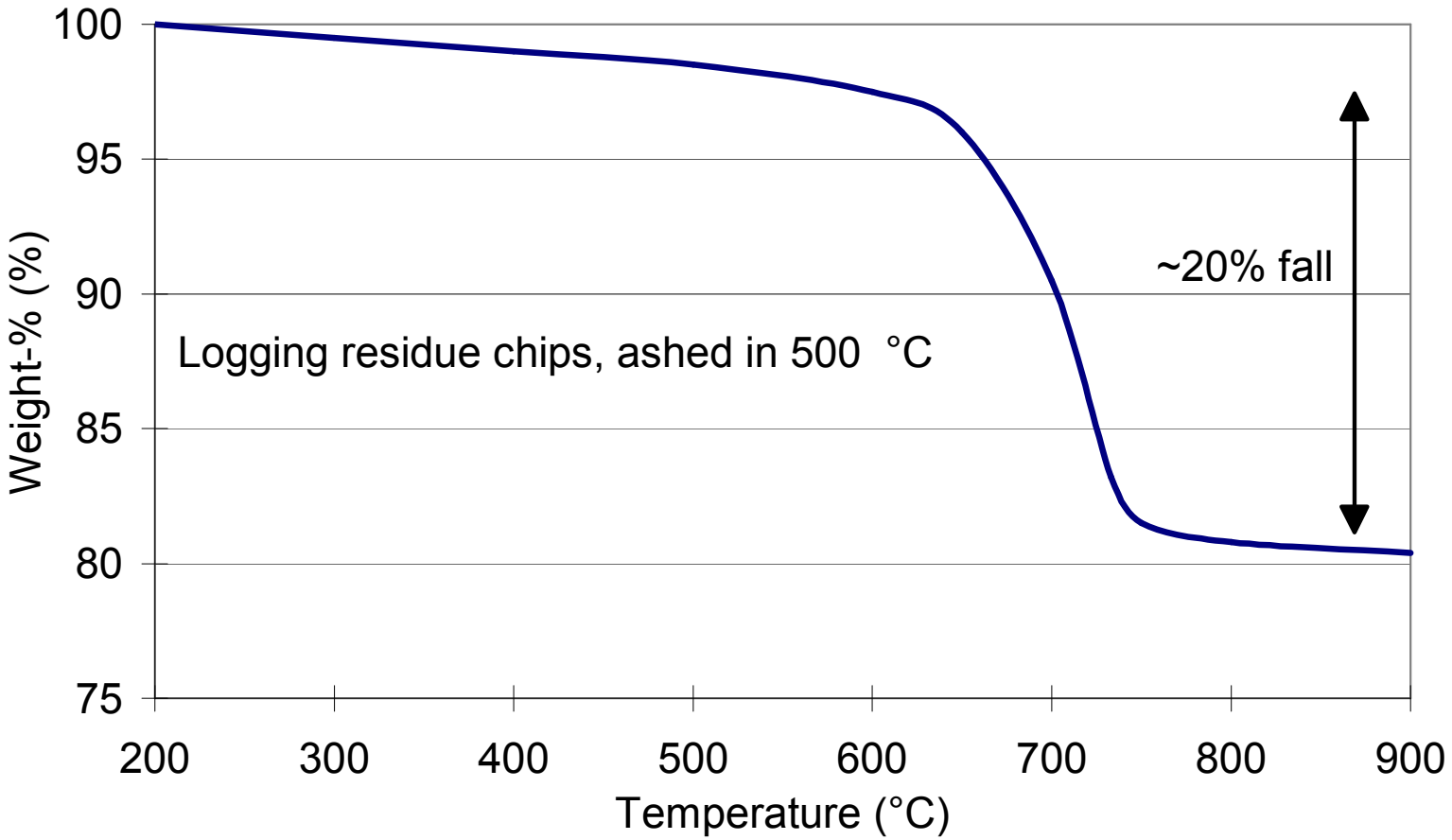
Sources of contributing elements




Sulphur content
SO2 emission
SO2 emission
Sulphur content (wt-%)
0.3
0.2
0.1
0
lr100
lr90/c10
wc60/b40
wc48/b42/c10
p63/lr37
p54/b23/lr23
p61/b39
p43/b33/c23
c56/b44
p95/c5
p49/b26/c25
p26/c50/lr24
p57/c43
c100
p47/b28/c25 +L
c50/b32/p18 +L
c50/b32/p18 +L +FA

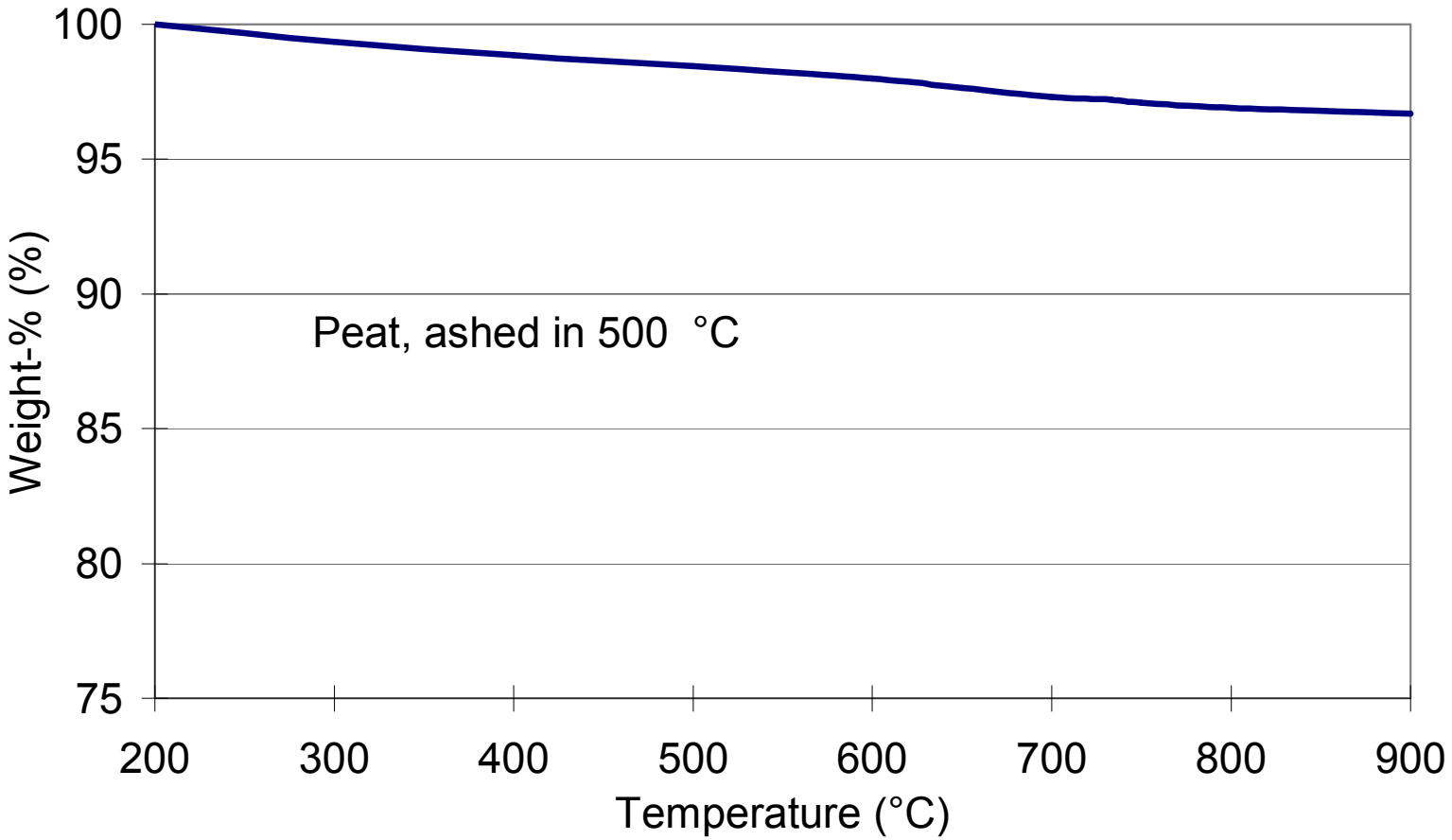

SO2 reduction
S02 reduction
SO2 reduction with limestone feeding
0
10
20
30
40
50
60
70
80
90
100
Share of biomass in fuel blend (%)

Sources of contributing elements: *TGA test*



Courtesy of Markku Orjala

Sources of contributing elements: *TGA test*



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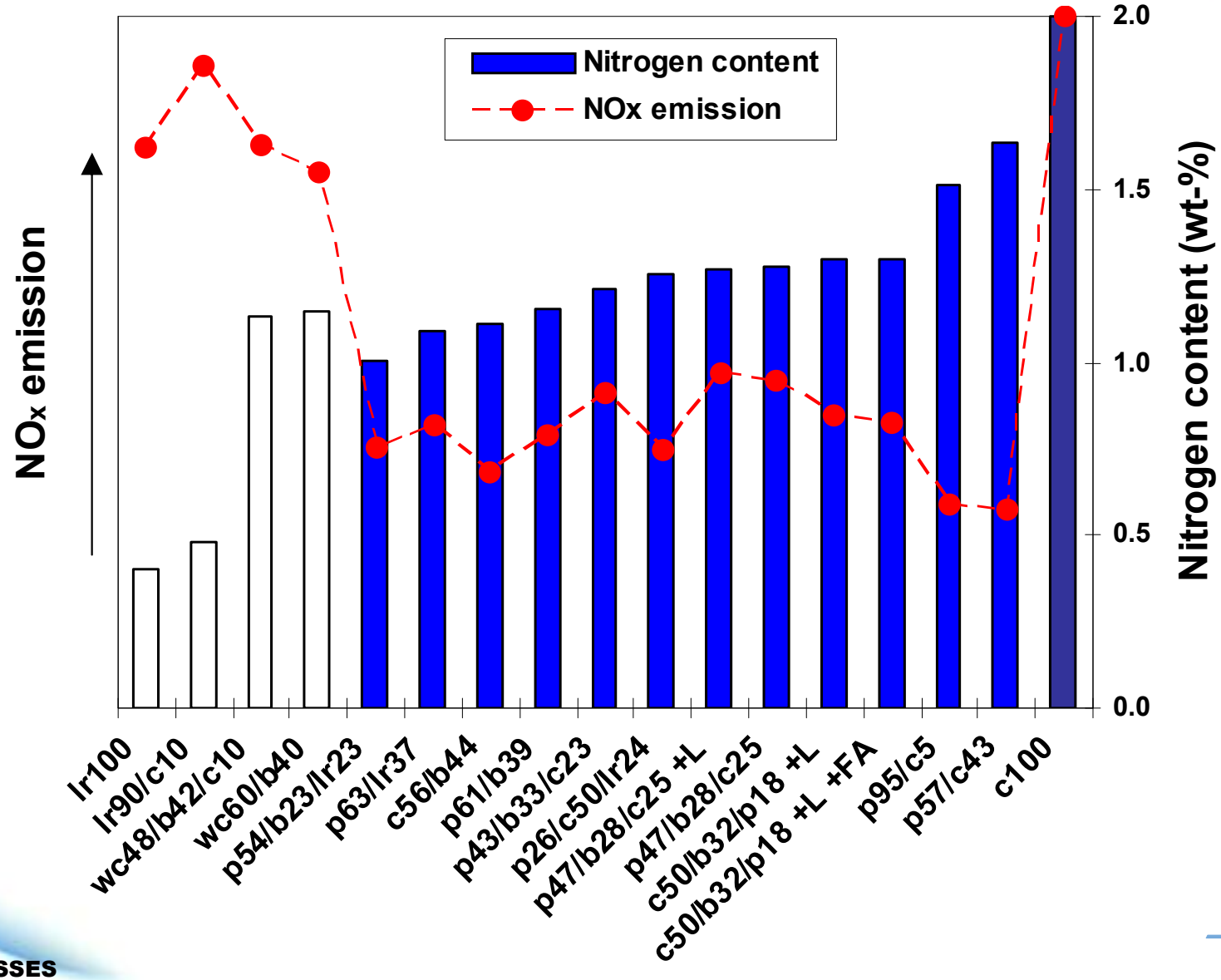
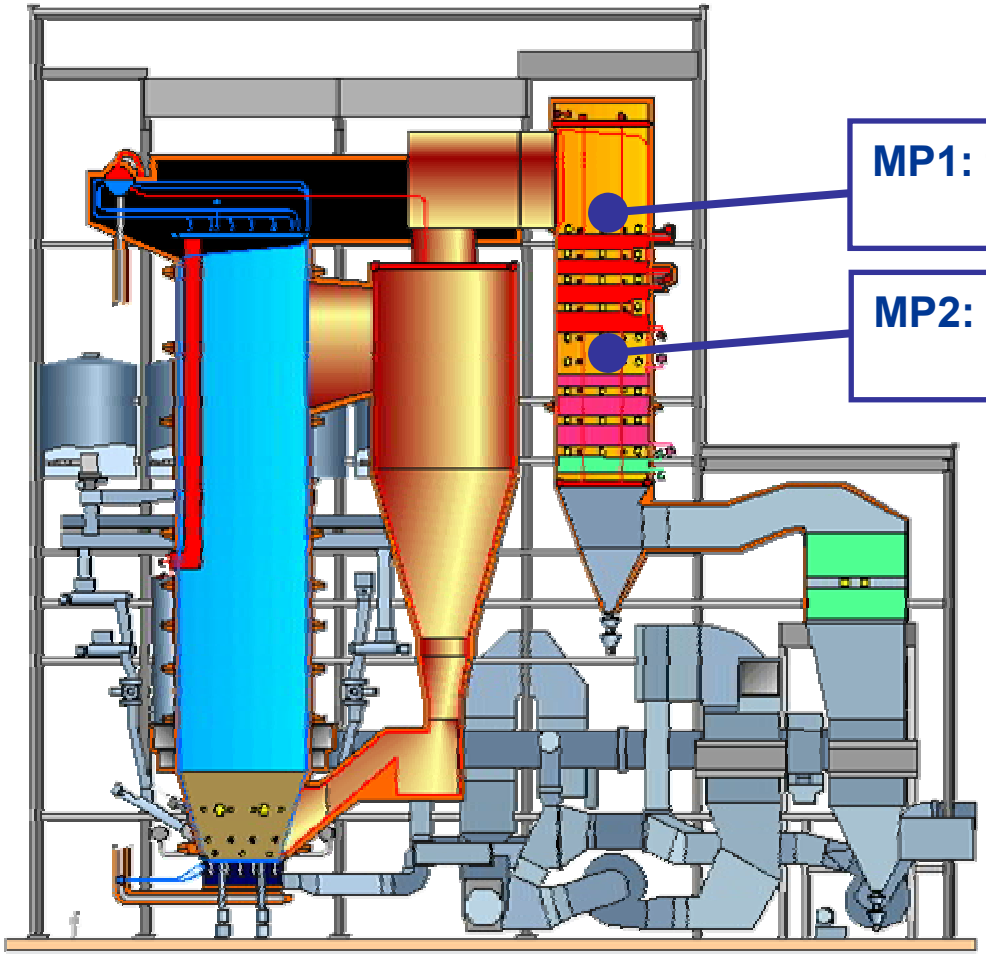

Nitrogen content
NOx emission
NOx emission
Nitrogen content (wt-%)
2.0
1.5
1.0
0.5
0.0
lr100
lr90/c10
wc48/b42/c10
wc60/b40
p54/b23/lr23
p63/lr37
c56/b44
p61/b39
p43/b33/c23
p26/c50/lr24
p47/b28/c25 +L
p47/b28/c25
c50/b32/p18 +L
c50/b32/p18 +L +FA
p95/c5
p57/c43
c100

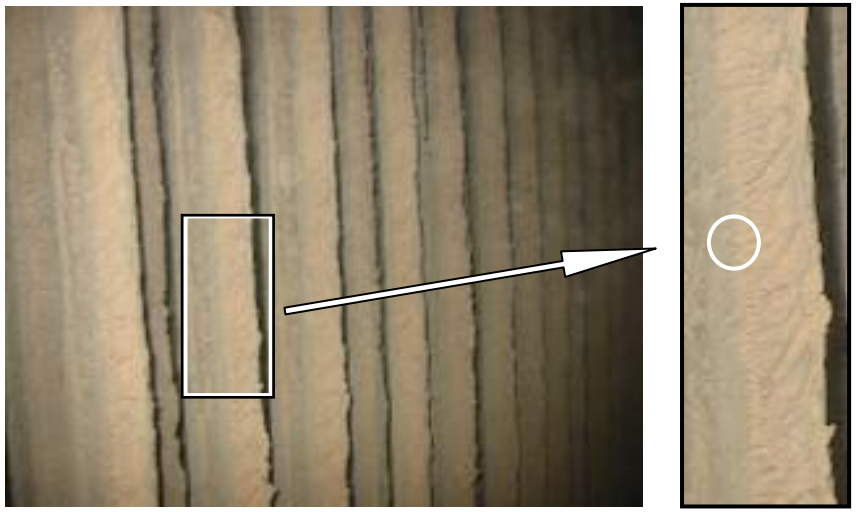
Deposit probe locations

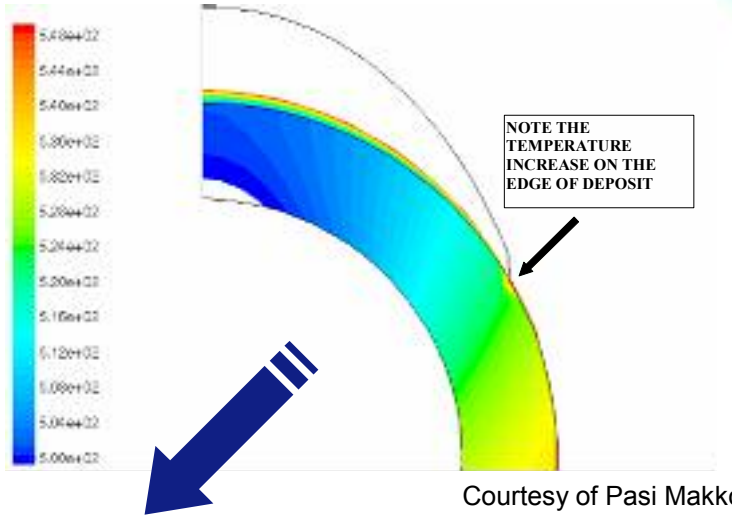


MP1: flue gas 700-750°C
probe 540°C

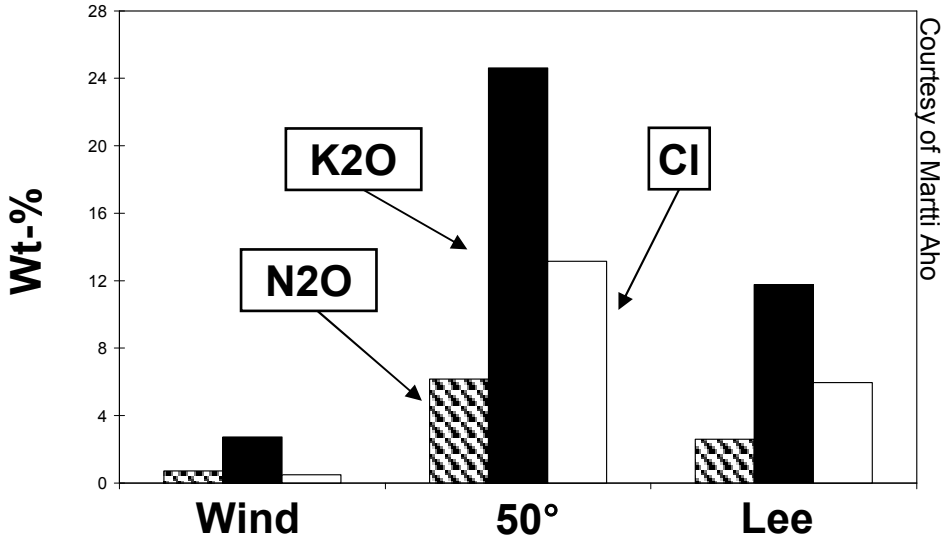
MP2: flue gas 510-550°C
probe 350°C

Radial variation in composition and temperature





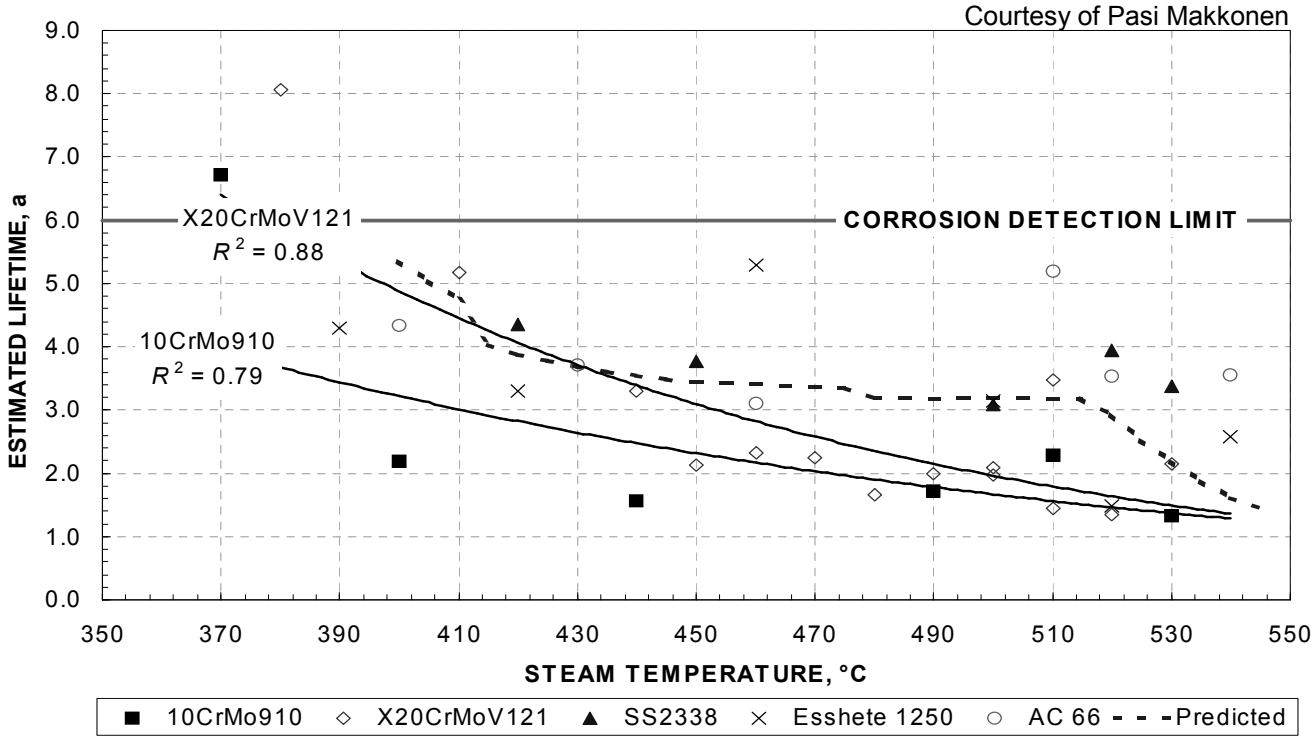
Courtesy of Pasi Makkonen



Courtesy of Martti Aho

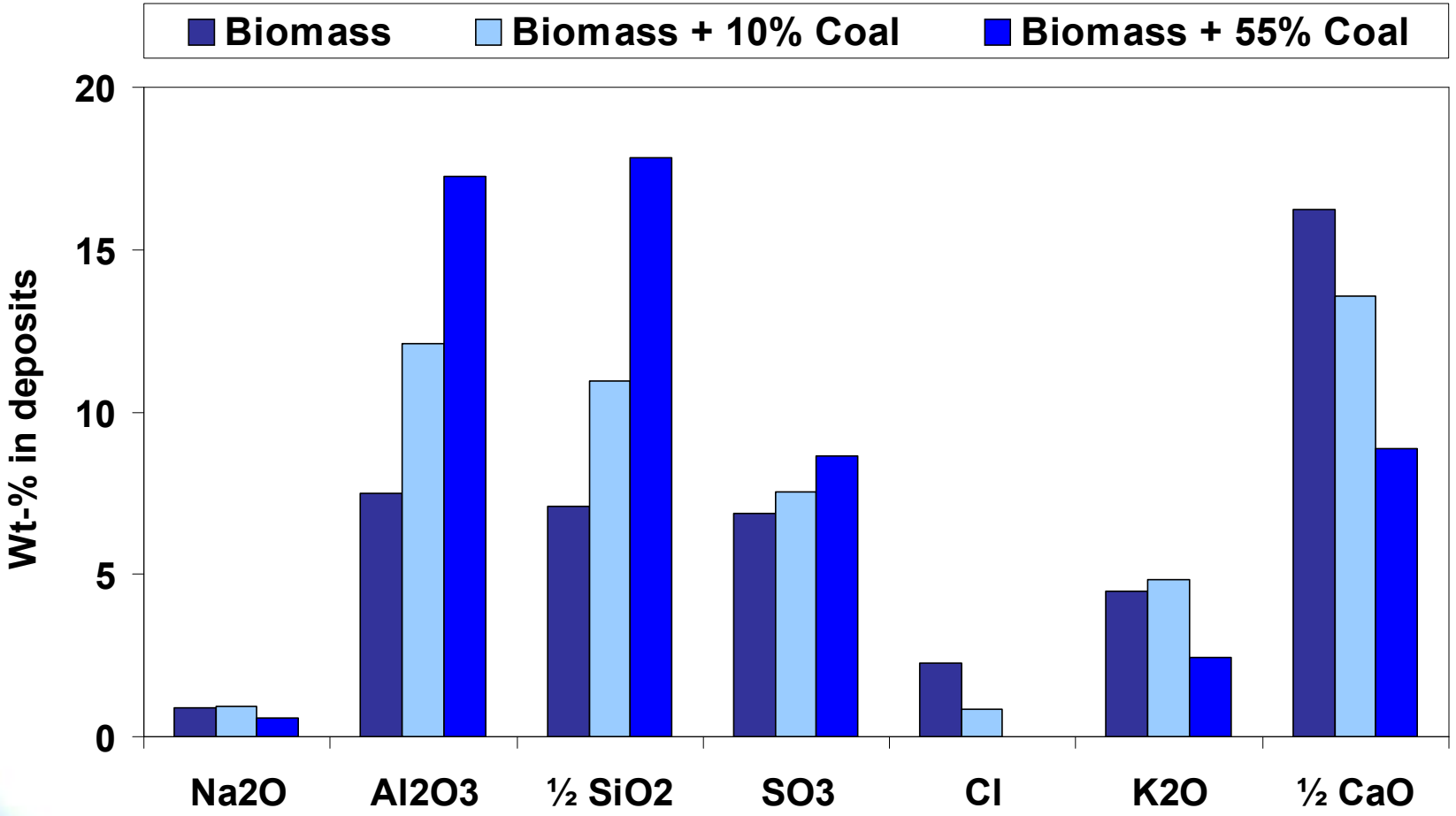
Boundary conditions: Temperature

Courtesy of Pasi Makkonen

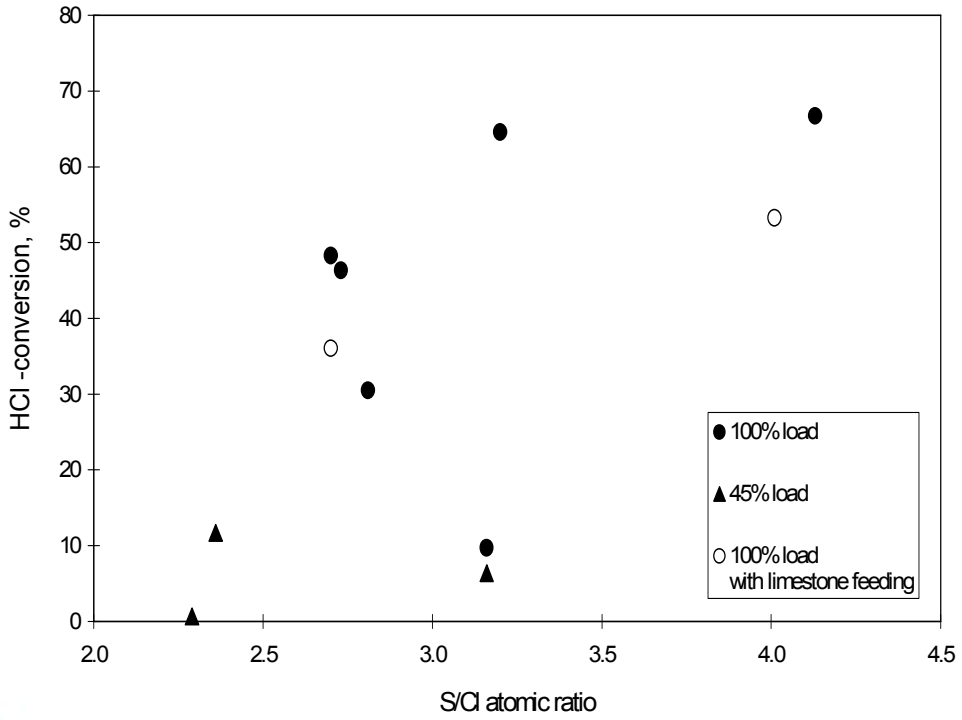


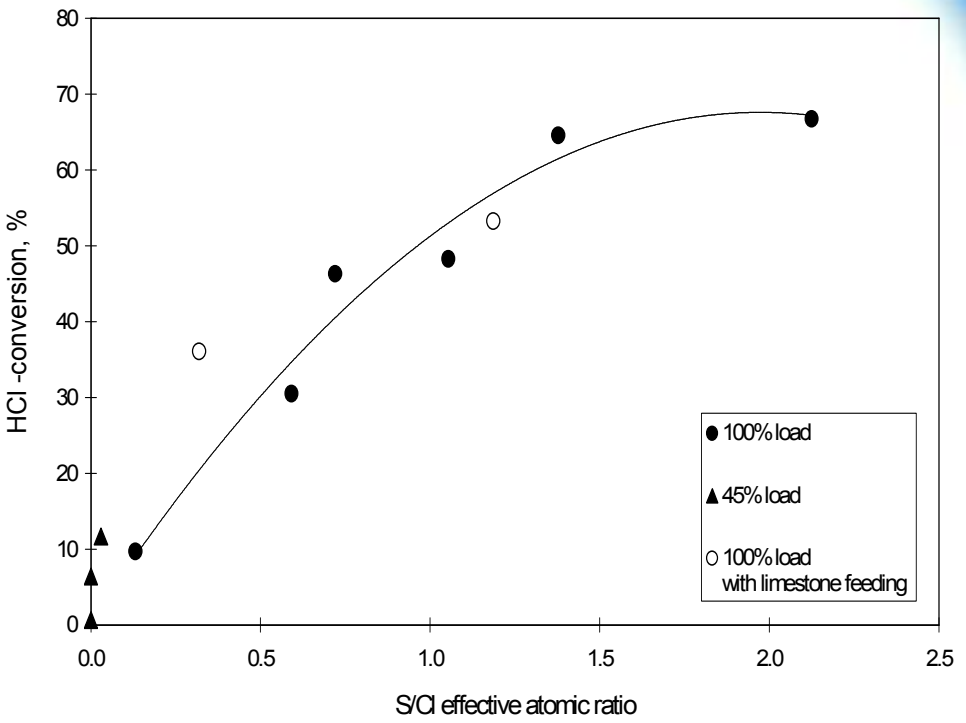
- **Dr Salmenoja: ~450°C is a threshold temperature for chlorine induced corrosion**
  - **supports findings of Dr Makkonen**
- **This corresponds to 400-415°C steam temperature**
- **On average, ~415°C is reached after 1st superheater in T_{LS}>500°C CFB/BFB**

Composition in 50° angle 350°C probe



Means to avoid chlorine corrosion: Sulphur



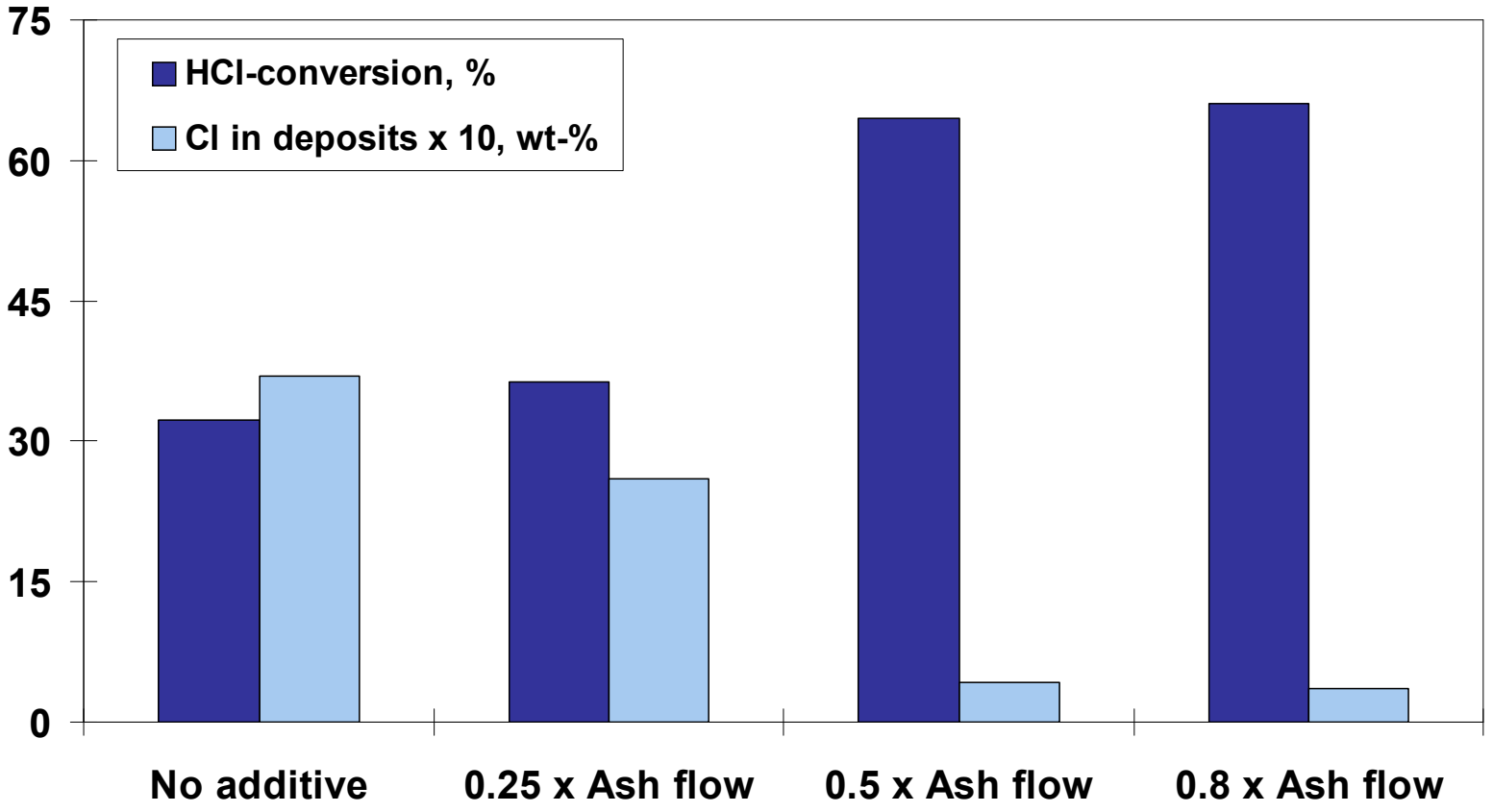


- **Sulphation of alkali chlorides:**

$$2KCl + SO_2 + \tfrac{1}{2} O_2 + H_2O \rightarrow K_2SO_4 + 2HCl$$

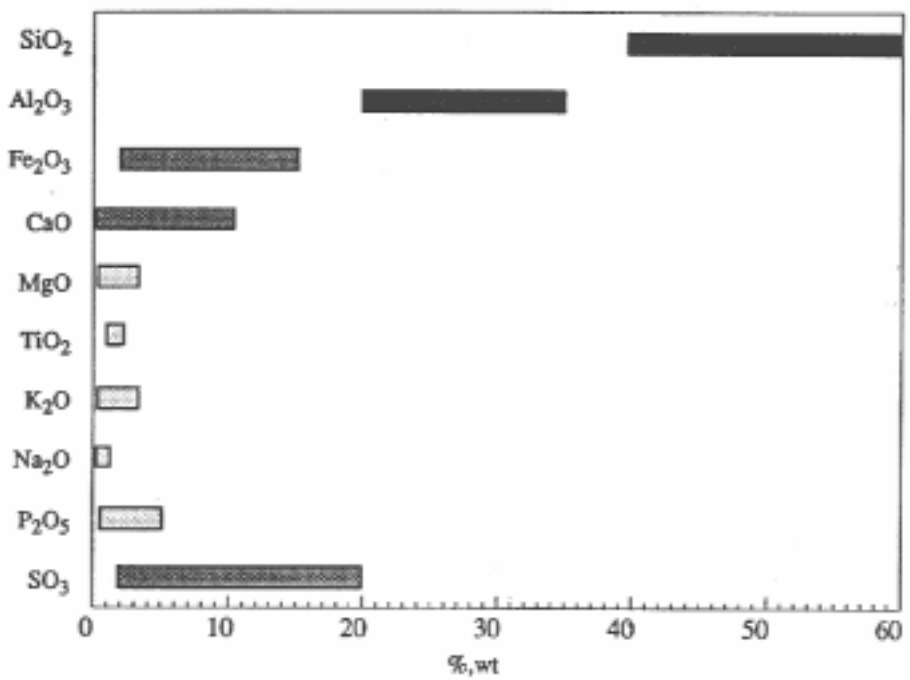
- **Gas phase effect!**

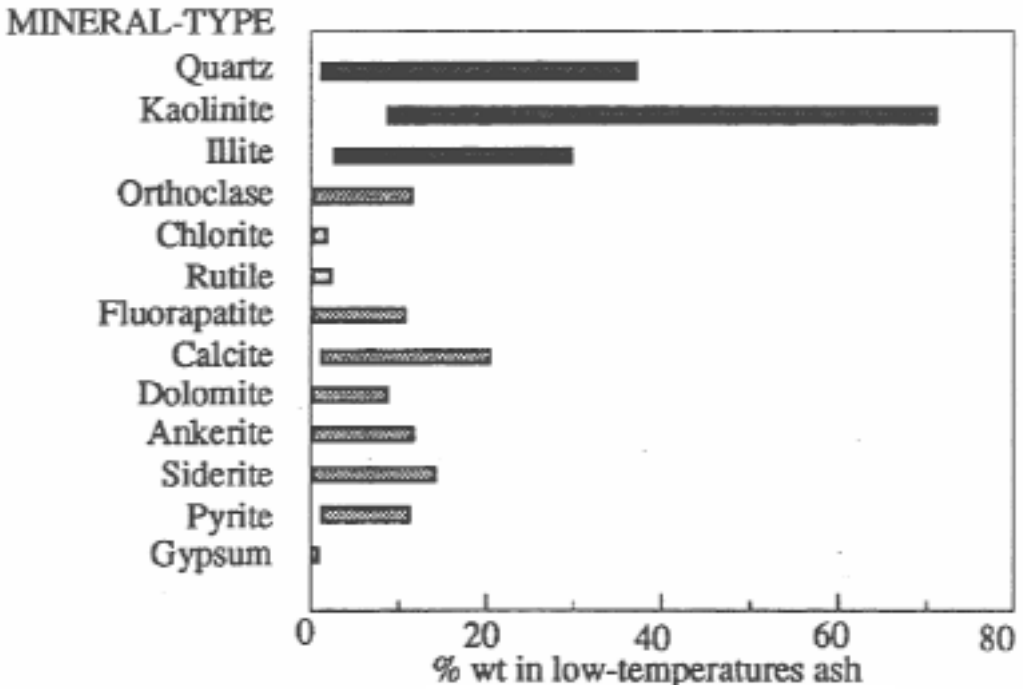
Means to avoid chlorine deposition: Aluminosilicates



- Kaolin, $Al_2O_3 \cdot 2SiO_2$, was fed to the bed (BFB)
- Dosing: 25, 50 and 80wt-% of the ash flow
- Fuel 20% AGW + 80% Bark

Means to avoid chlorine corrosion: Coal minerals





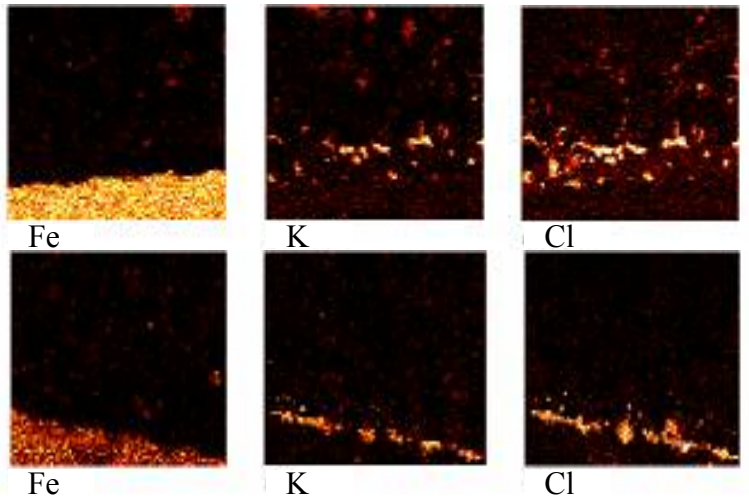
- **Alumininosilicates** can also react with alkalis liberating HCl:

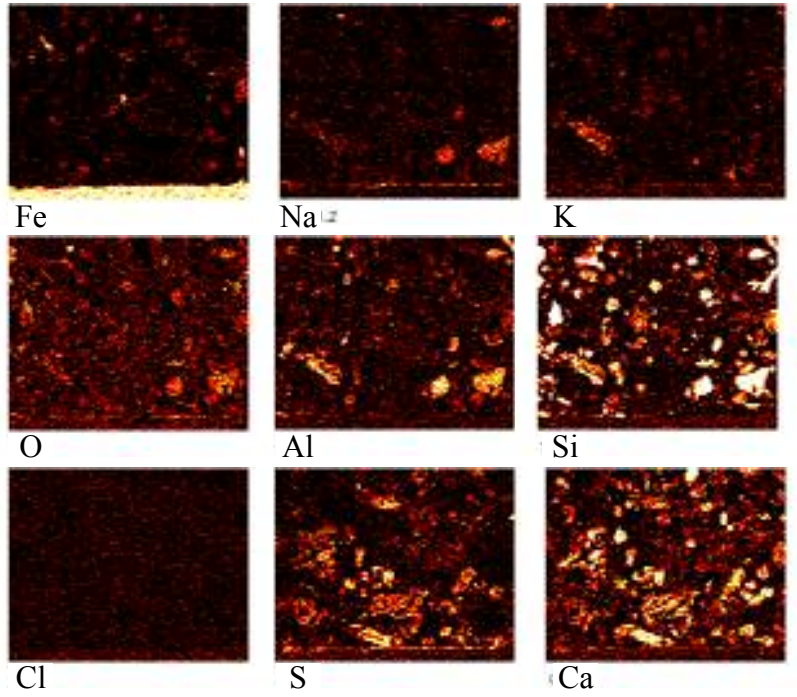
$$Al_2Si_2O_7 \cdot 2H_2O \rightarrow Al_2O_3 \cdot 2SiO_2$$

$$Al_2O_3 \cdot 2SiO_2 + 2KCl + H_2O \rightarrow K_2O \cdot Al_2O_3 \cdot 2SiO_2 + 2HCl$$

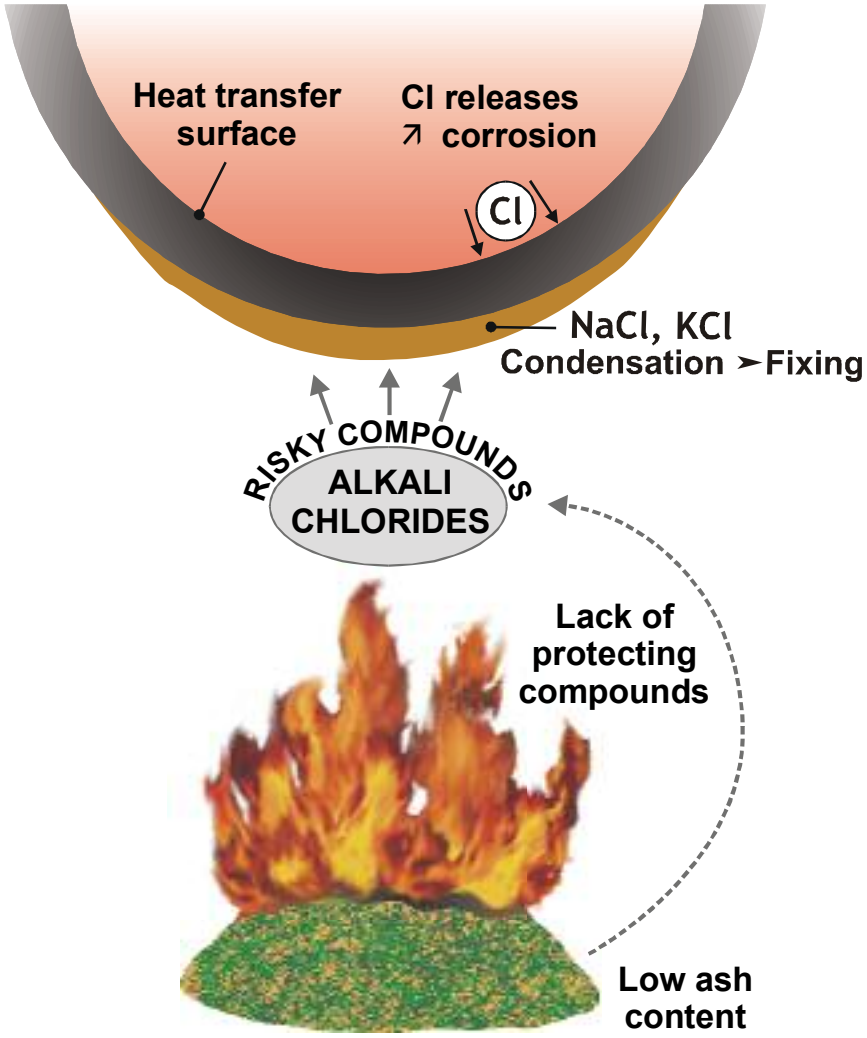
- The most abundant mineral is **kaolinite** (above) and **illite** (or range of aluminosilicates)
- The key issue is whether there is alkali metal **bound already** in the aluminosilicate

The objective

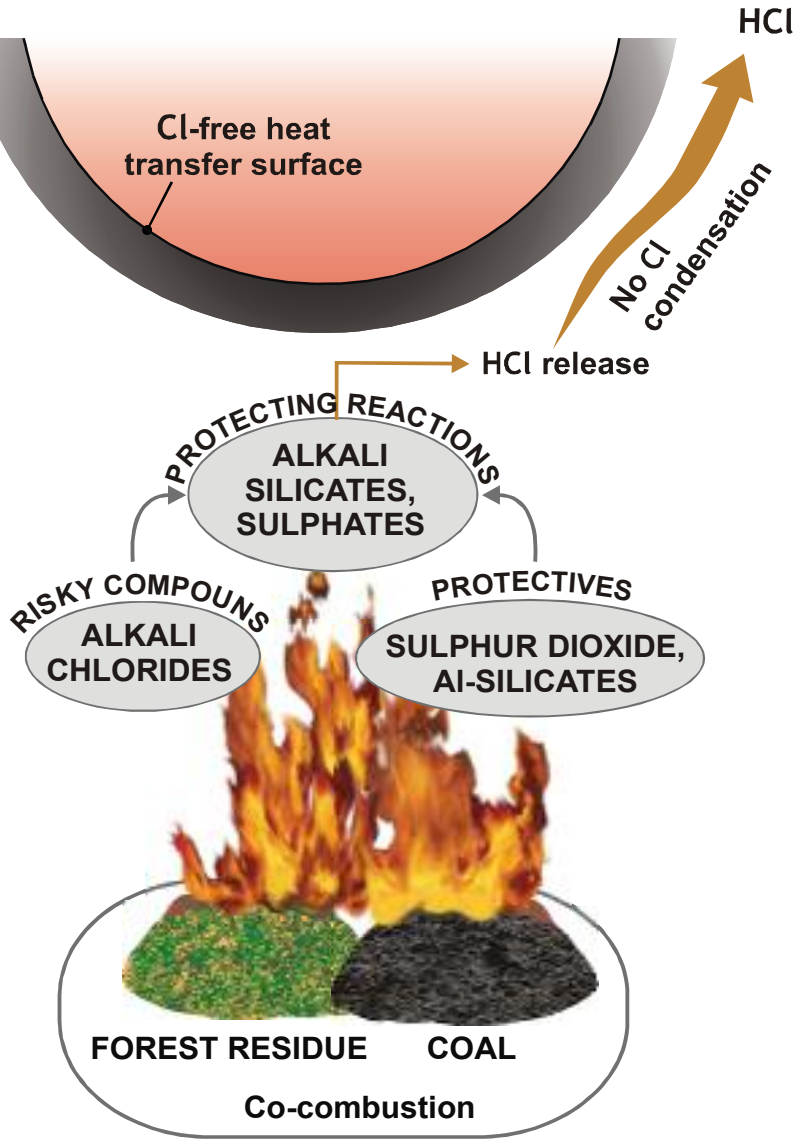




CASE 1. BARK/FOREST RESIDUE



CASE 2. PROTECTING POWER OF COAL



Conclusions

- In CFB conditions high SO_2 autoreduction can be achieved by cofiring biomass with peat and/or coal due to high Ca content of wood fuels
- In CFB conditions peat/wood/coal cofiring produces less NOx than pure coal or wood fuel firing
- Chlorine bearing deposit formation can be avoided by appropriate fuel blending. 'Protective elements' can be supplied in the boiler in peat and/or coal ash
- As a result of fuel blending, change in the composition of fuel ash can dramatically change ash melting behaviour
- S/Cl atomic ratio in fuel is not an appropriate parameter in describing corrosion propensity of fuel blends in biomass cofiring. Instead, estimation for this ratio in gas phase could be used as a guideline
- With higher shares of peat and especially coal, the effect of aluminium silicates should also be assessed
- The amount of nitrous oxide, N2O, increases steeply when coal is blended to the biomass blend. This could be an issue if there will be emission limits for this compound in the future