

# Reinhold Environmental Ltd.



## 2010 NO<sub>x</sub>-Combustion Round Table & Expo Presentation

***February 8 & 9, 2010***

***Chattanooga, TN***

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## Biomass Co-Firing Impact on NO<sub>x</sub>, Catalyst, and SCR Operation

2010 NO<sub>x</sub>-Round Table, Chattanooga, TN

Workshop 23 - February 9, 2010

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## Agenda

- Introduction Co-Firing
- Introduction Power Plant Maasvlakte
- Operational Experience SCR
- Formation of Blinding Layers
- Co-firing of Biomass – Improved Analytical tools

## Drivers for Co-Firing of Biomass

### Why Biomass?

- Political and social concerns about Global Warming (CO<sub>2</sub> neutral)
- Wildly available, "renewable"
- Economical (incentified)

Carbon Intensity E.ON Group							
in t/MWh							
Central Europe	0.45	0.41	0.41	0.41	0.41	0.42	0.39
U.K.	0.94	0.72	0.79	0.75	0.71	0.73	0.58
Nordic	0.02	0.14	0.01	0.01	0.02	0.01	0.01
U.S. Midwest	0.99	1.00	0.93	0.92	0.93	0.94	0.92
Russia	-	-	-	-	-	-	0.59
<b>E.ON Group</b>	<b>0.72</b>	<b>0.55</b>	<b>0.49</b>	<b>0.49</b>	<b>0.49</b>	<b>0.50</b>	<b>0.48</b>

- **E.ON's goal is to halve the Carbon intensity by 2030 from 1990 levels**

### Why co-firing?

- Short term realization at low capital and operating cost
- More efficient (coal fired plant ~35%, biomass plant ~25%)
- "Economy of scale" (average coal plant ~ 500 MW, biomass plant 20-50MW)

## Co-Firing of Biomass in Europe

- Widely used in Europe

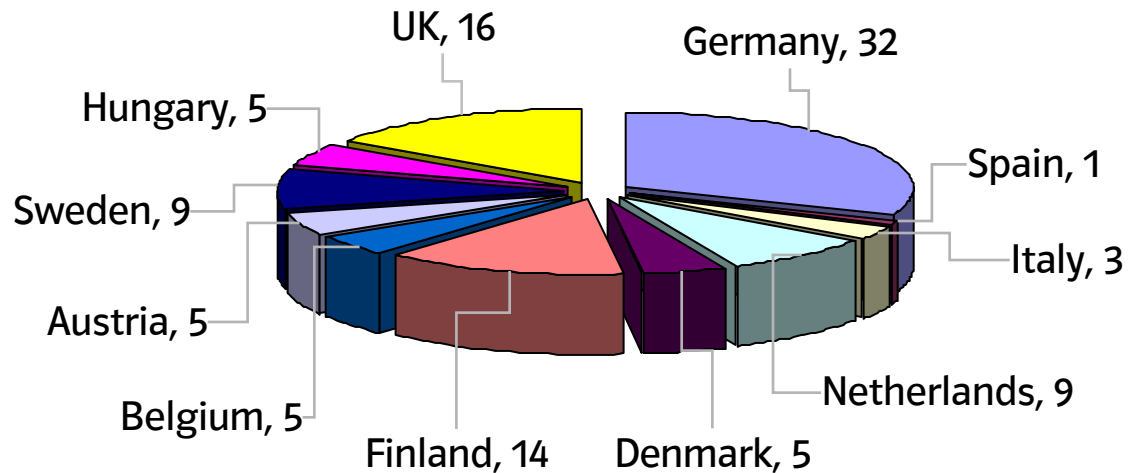
- E.ON Group:

- Moderate activity on co-firing at most

German coal-fired power plants, typical feeding rates 2-10 wt-%

- Significant activity at most of the coal-fired power plants in the UK, feeding rates of 10 – 20 wt-%

- Significant activities at E.ON's coal-fired power plants in the Netherlands, feeding rates of 20 – 30 wt-%, aiming for up to 50 wt-%



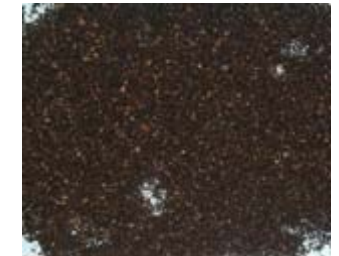
## Co-Firing Biomass Maasvlakte

- 2 x 540 MW<sub>el</sub> pulverized coal tangentially fired
- Dry bottom boiler, bituminous coal
- Subcritical steam (183 bar/ 47 bar, 540 °C)
- Low-NO<sub>x</sub> burners, overfire air
- High dust SCR, ESP, wet FGD
- Efficiency 40,6 %
- Depends on availability



## Maasvlakte - Biomass Experience

- Wood pellets
- Meat and bone meal
- Coffee (dry and wet)
- Paper sludge pellets
- Animal fat
- Olive cake
- Sheanut scraps
- Biomass pellet
- Soya hulls
- Poultry litter
- Citrus pellets
- Anode cokes
- Cardboard
- Rapeseed scraps
- Rice pellets
- Sewage sludge
- Petroleum cokes
- ...



## Maasvlakte - Handling the Biomass

- Biomass building



- Bone meal installation

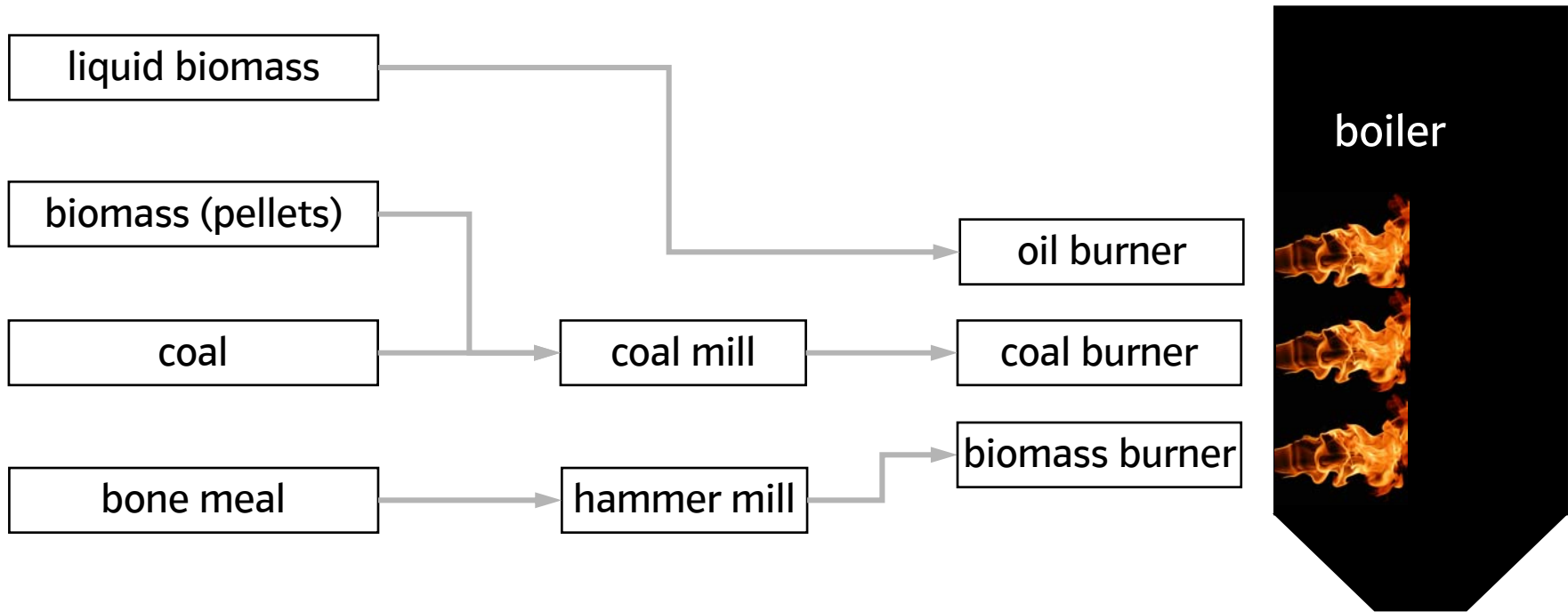


- Rest fuels Wood, grass, etc.

- Direct on the coal



## Maasvlakte - Feeding Biomass into the Boiler



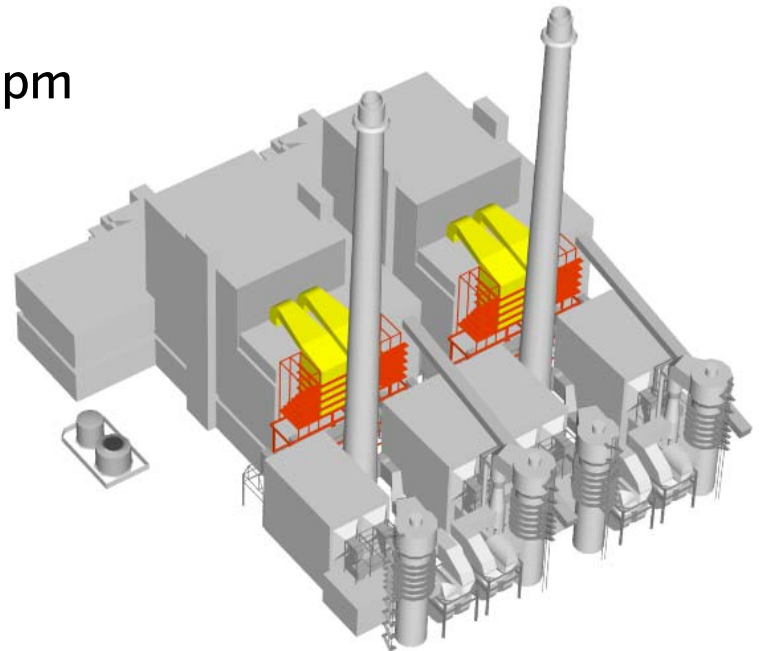
## Maasvlakte – Operational Experience SCR

### Design requirements

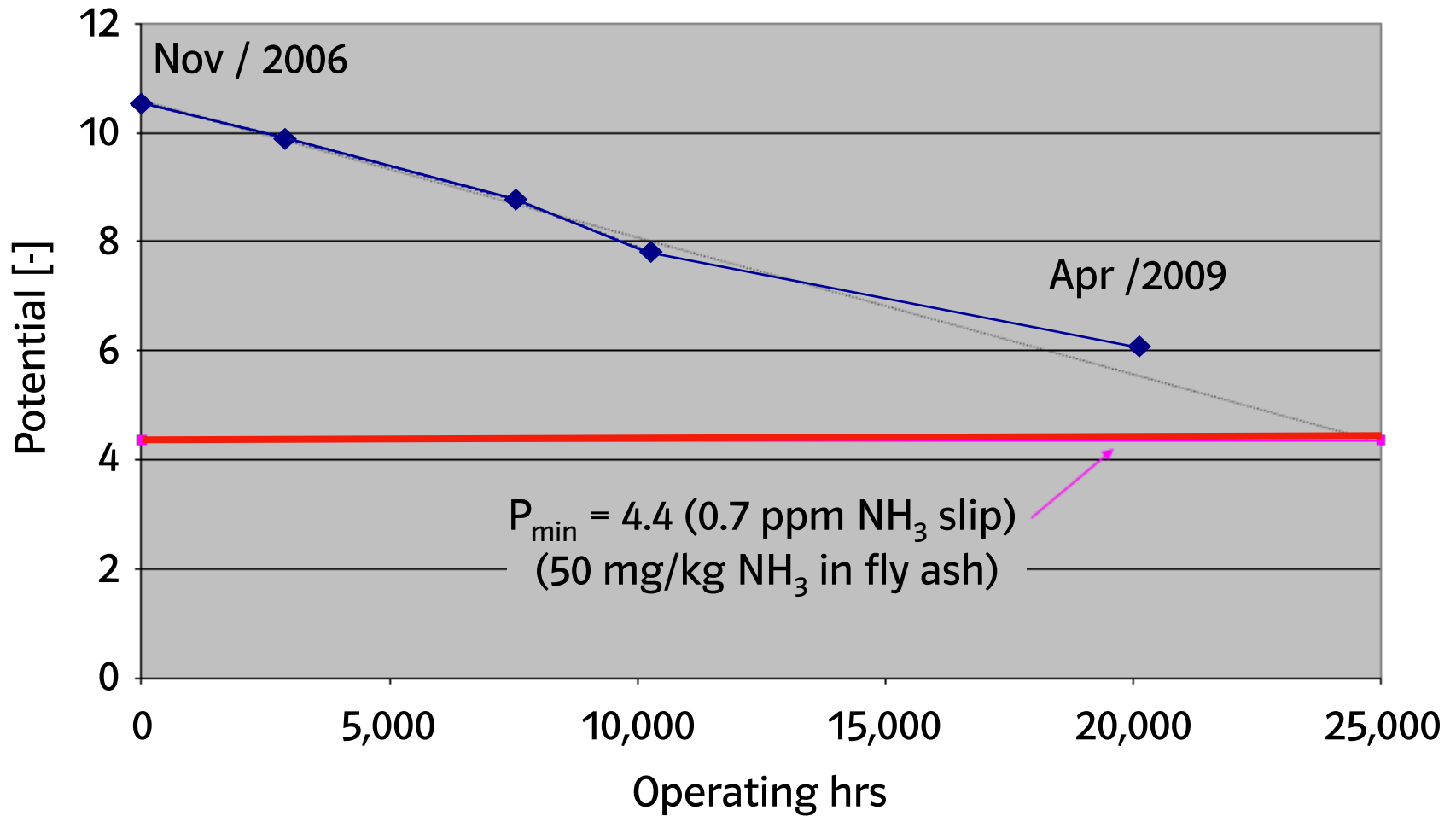
- High dust SCR retrofited in 2007
- Ammonia in Fly ash is limited to 50 mg/kg
- NO<sub>x</sub> reduction up to 29.6ppm (60 mg/Nm<sup>3</sup>)
- Efficiency up to 88%
- Maximum tolerable ammonia slip is 0.7 ppm
- 3 years revision cycles
- Co-Firing

### Design

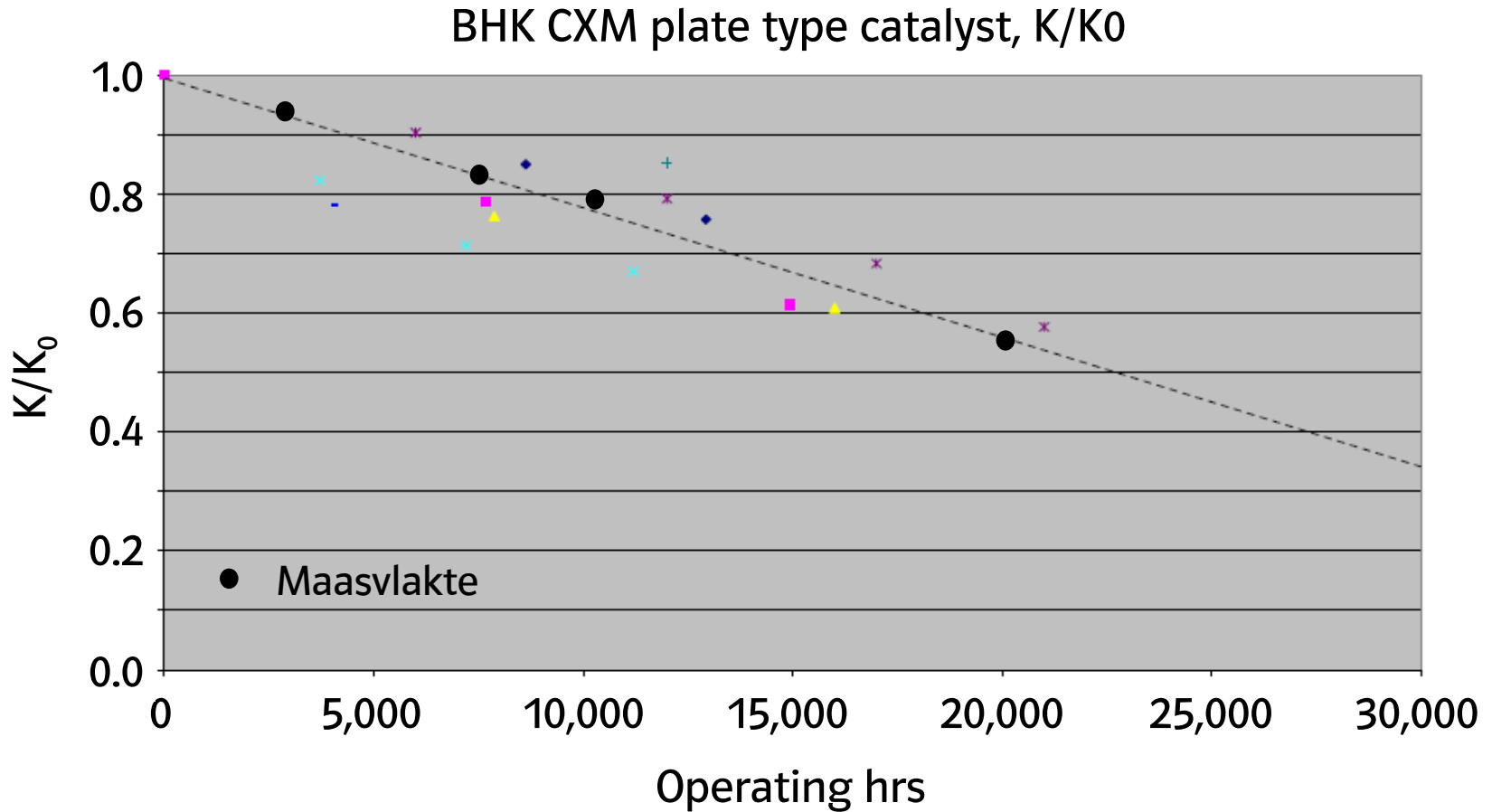
- 2 reactors per Unit
- 4+1 layer design
- BHK CXM plate catalyst
- Start potential P=10.4



## Deactivation Rate in Maasvlakte Power Plant

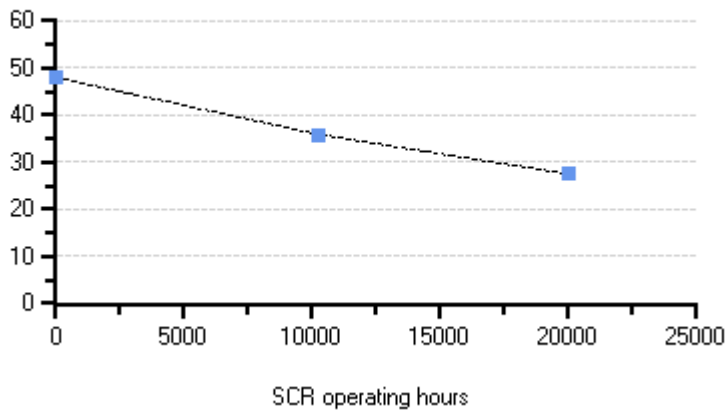


## Comparison of Deactivation Rates in E.ON Power Plants

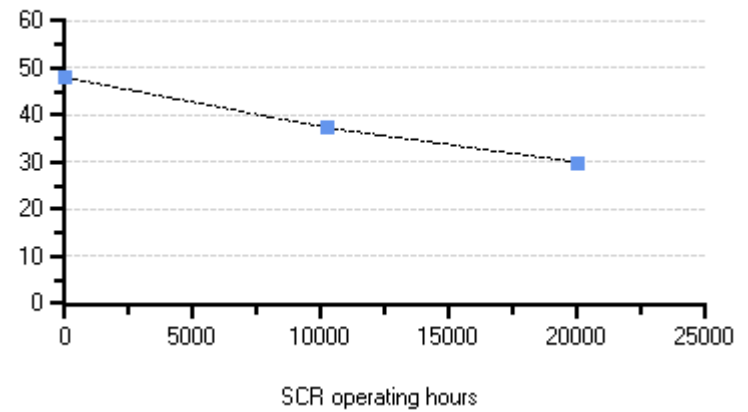


# Layer dependent deactivation

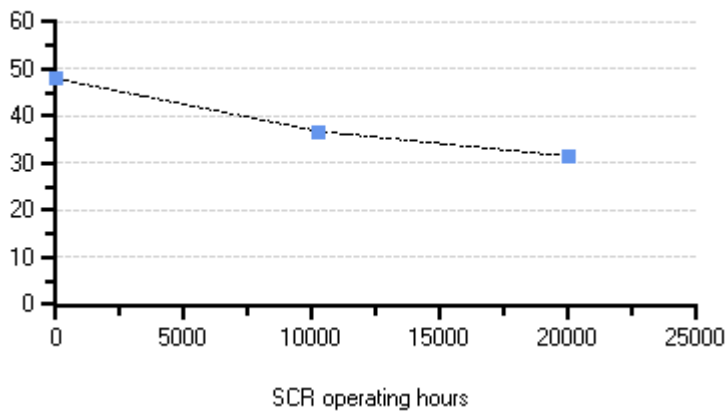
Activity constant Layer 1



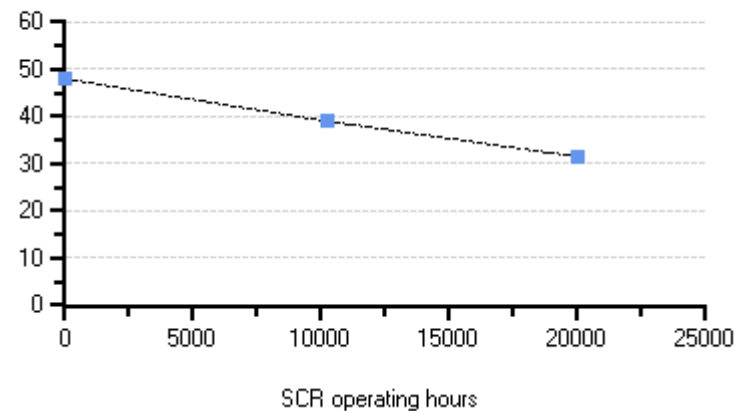
Activity constant Layer 2



Activity constant Layer 3



Activity constant Layer 4



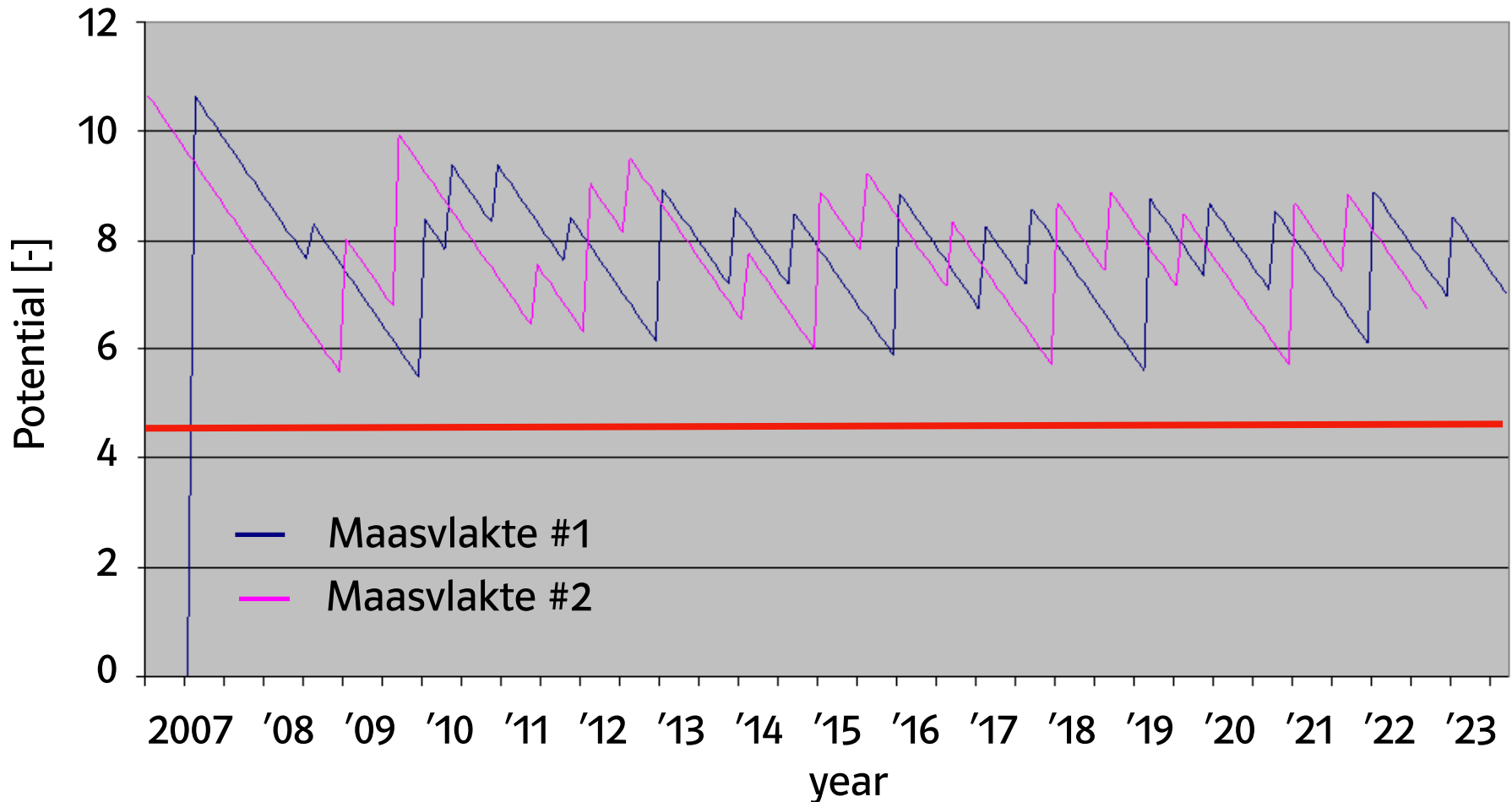
# SCR Operation Maasvlakte

- Deactivation rate: not accelerated compared to other E.ON power plants utilizing same catalyst material
- However, Nov 2006 – Apr 2009 (~ 2.5 years) heavy losses in Potential (>4)

Revision Planning (ver. 2008)																
year	2008	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23
<b>MV1</b>			6wk			4wk			4wk			4wk			2wk	
<b>MV2</b>		6wk			4wk			4wk			4wk			2wk		
Catalyst changes																
<b>MV1</b>	1		2 1	1	1	2	1	1	2	1	1	2	1	1	2	
<b>MV2</b>		2 2		1	2 1		1	2	1	1	2	1	1	1		

## SCR Operation Maasvlakte

- Catalyst Potential over time according to current revision strategy



## SCR Operation Maasvlakte

- Deactivation due to formation of blinding layer, Arsenic poisoning and the loss of  $\text{MoO}_3$

### XRF Surface Analysis

	New	Layer 1		Layer 2		Layer 3		Layer 4		
		In	Out	In	Out	In	Out	In	Out	
$\text{SiO}_2$	%	14,4	17,2	17,7	15,5	15,3	17,9	16,8	16,9	15,2
$\text{Al}_2\text{O}_3$	%	8,8	7,8	7,8	7,3	5,9	8,9	7,8	8,0	7,0
$\text{Fe}_2\text{O}_3$	%	0,43	1,7	0,99	0,56	0,86	1,6	1,3	1,9	1,5
$\text{TiO}_2$	%	67,9	59,2	61,4	61,6	65,4	56,5	62,3	56,2	62,7
$\text{CaO}$	%	< 0,03	0,80	0,65	0,78	0,51	0,86	0,54	0,95	0,65
$\text{MgO}$	%	0,04	0,60	0,41	0,45	0,27	0,50	0,38	0,48	0,31
$\text{Na}_2\text{O}$	%	< 0,03	0,48	0,27	0,53	0,23	0,52	0,26	0,59	0,25
$\text{K}_2\text{O}$	%	< 0,03	0,19	0,15	0,28	0,12	0,32	0,18	0,29	0,16
$\text{SO}_3$	%	0,24	5,4	4,0	6,2	4,3	6,6	4,2	8,2	5,2
$\text{P}_2\text{O}_5$	%	0,03	1,6	1,2	1,7	1,1	1,8	1,5	1,8	1,2
$\text{V}_2\text{O}_5$	%	1,6	1,6	1,7	1,6	1,6	1,5	1,3	1,6	1,7
$\text{MoO}_3$	%	6,3	2,6	3,0	3,0	3,7	2,5	3,0	2,7	3,5
As	ppm	20	5.380	2.890	2.260	1.280	1.970	1.430	1.430	1.080

## SCR Operation Maasvlakte

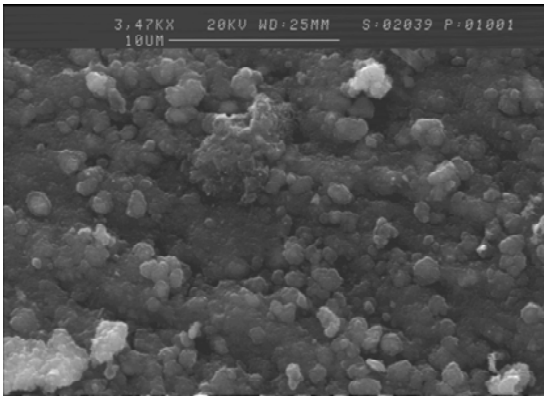
- Deactivation due to formation of blinding layer, Arsenic poisoning and the loss of  $\text{MoO}_3$

### XRF Bulk Analysis

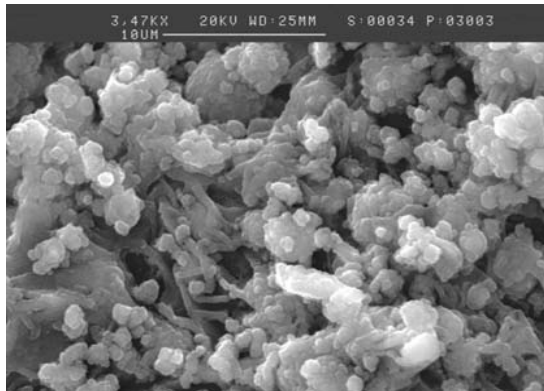
	New	Layer 1		Layer 2		Layer 3		Layer 4		
		In	Out	In	Out	In	Out	In	Out	
$\text{SiO}_2$	%	14,4	17,2	16,9	16,3	17,5	17,7	17,4	16,8	16,9
$\text{Al}_2\text{O}_3$	%	8,8	7,7	7,1	7,0	7,4	7,7	7,2	7,3	7,3
$\text{Fe}_2\text{O}_3$	%	0,43	2,2	1,24	2,9	2,0	2,6	2,3	1,66	1,44
$\text{TiO}_2$	%	67,9	63,8	66,1	63,4	64,8	61,8	64,6	64,8	65,2
$\text{CaO}$	%	< 0,03	0,14	0,07	0,12	0,09	0,10	0,08	0,08	0,07
$\text{MgO}$	%	0,04	0,04	0,03	0,05	0,03	0,03	0,03	0,03	0,03
$\text{Na}_2\text{O}$	%	< 0,03	0,03	0,04	0,18	0,03	0,17	0,03	0,05	0,04
$\text{K}_2\text{O}$	%	< 0,03	0,36	0,18	0,45	0,20	0,38	0,17	0,33	0,21
$\text{SO}_3$	%	0,24	2,2	1,58	3,3	1,81	3,1	1,88	2,3	1,90
$\text{P}_2\text{O}_5$	%	0,03	0,04	0,10	0,20	0,06	0,20	0,04	0,08	0,09
$\text{V}_2\text{O}_5$	%	1,56	2,1	1,93	1,5	1,89	1,52	1,92	2,2	2,1
$\text{MoO}_3$	%	6,3	3,5	4,3	3,8	4,0	4,2	4,1	4,2	4,5
As	ppm	20	3.552	1.419	2.498	733	1.773	572	766	531

## Formation of blinding layer

Catalyst surface new



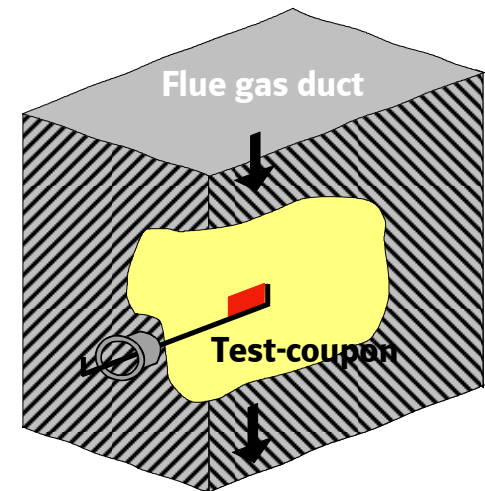
Catalyst surface with deposits



- strong deactivation of high dust catalyst while firing through blinding layer

### • Lab tests

- High content of CaO, MgO, Na<sub>2</sub>O, K<sub>2</sub>O, SO<sub>3</sub>, P<sub>2</sub>O<sub>5</sub>, SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> on outer surface
- Inner surface almost unchanged



### • Process optimization

- Determination of optimal dosage rate for specific power plant
- Early detection through coupon test

## Fouling - gaseous phosphates as a "bonding agent"



- Target: 5 % addition
- Massive deposits at 2 % addition of sewage sludge



### • Lab tests of deposits

Main components  $\text{SiO}_2$  and  $\text{Al}_2\text{O}_3$   
Containing As, S, P



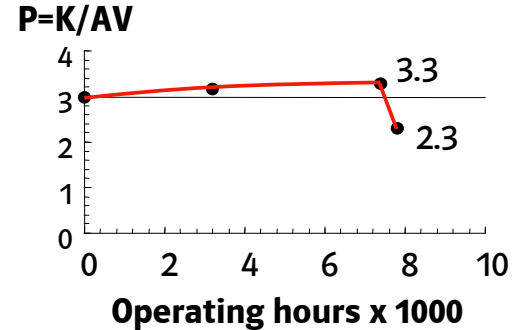
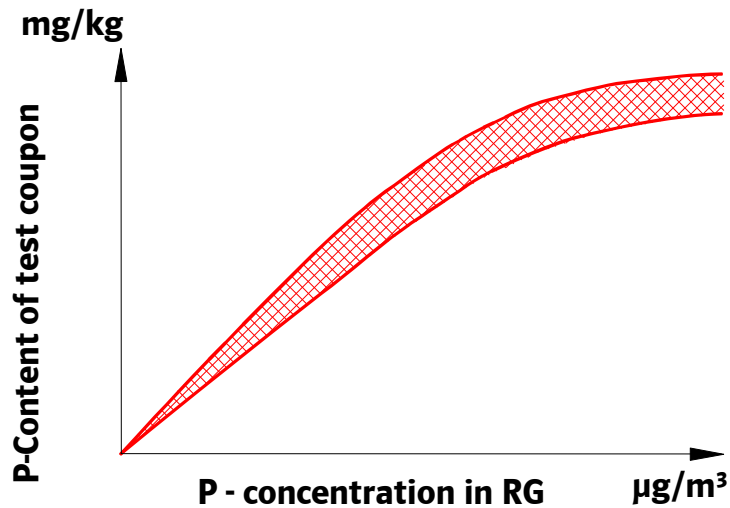
### • Process optimization

- Prevention of reducing conditions
  - Optimization of fuel distribution
  - Increase of primary air
- Improvement primary retention rate
  - Increase of milling degree
- Adjustment of sootblowing program

**➔ Operation with minimum failure rate using 5 % sewage sludge**

## Co-Firing Biomass – Severe Deactivation

- strong catalyst deactivation when co-combusting animal fat in oil-fired power plants



- **Lab tests**
  - strong increase of  $\text{SO}_3$  and  $\text{P}_2\text{O}_5$  on inner and outer catalyst surface
  - Coupon test revealed strong release of gaseous phosphates
  - Little ash as reaction partner for volatile phosphate
- **Process optimization**
  - Moving animal fat co-combustion to a coal-fired power plant

## Comparison of different Fuel Types

### Fuel Types

		Hard Coal	Lignite	Sewage Sludge	MBM	PRB Coal (Wyodak)
Na as Na <sub>2</sub> O	[wt-%]	1.51	2.7	0.4	5.9	0.9
K as K <sub>2</sub> O	[wt-%]	2.91	1.6	0.7	2.75	0.7
P as P <sub>2</sub> O <sub>5</sub>	[wt-%]	0.19	0.1	14.2	36.2	1.1

## Co-Firing of Biomass – Operational Experiences

### Main issues from experiences

- Grindability of the biomass/coal blend
- Capacity of existing unit components
- Combustion behavior, burn-out
- Quality of by-products
- Slagging, fouling
- Corrosion



## Testing Grindability , Ignition- and Combustion behavior

Degasification alembic

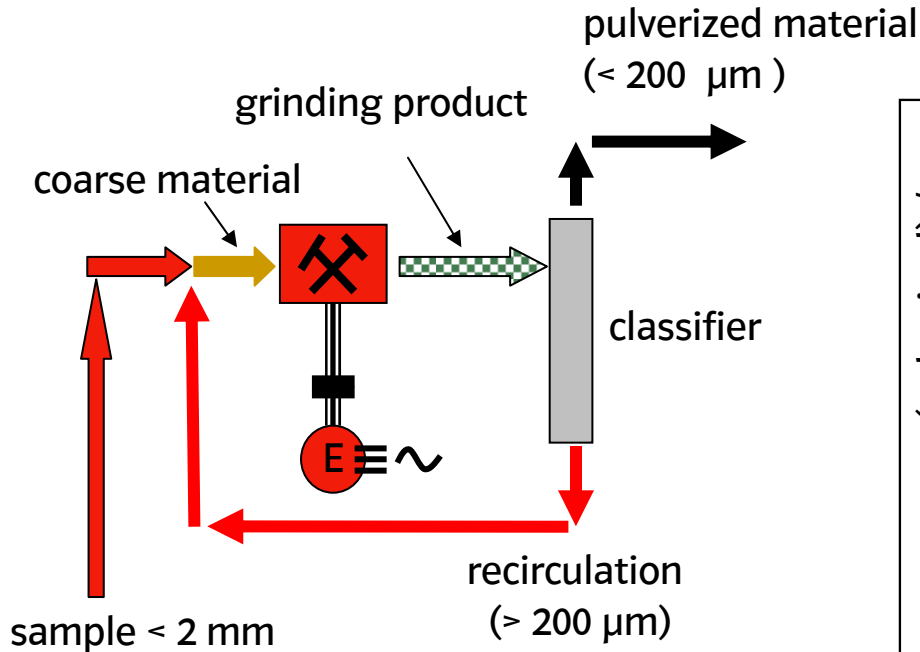


Ignition furnace

Grinding unit

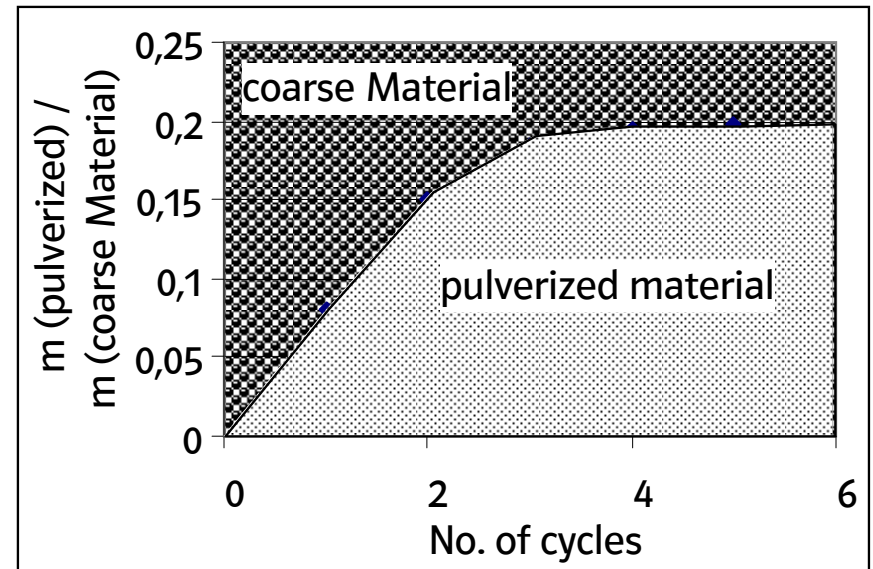


# Testing the Grindability



Grinding work  $E_m$  [kWh/t]

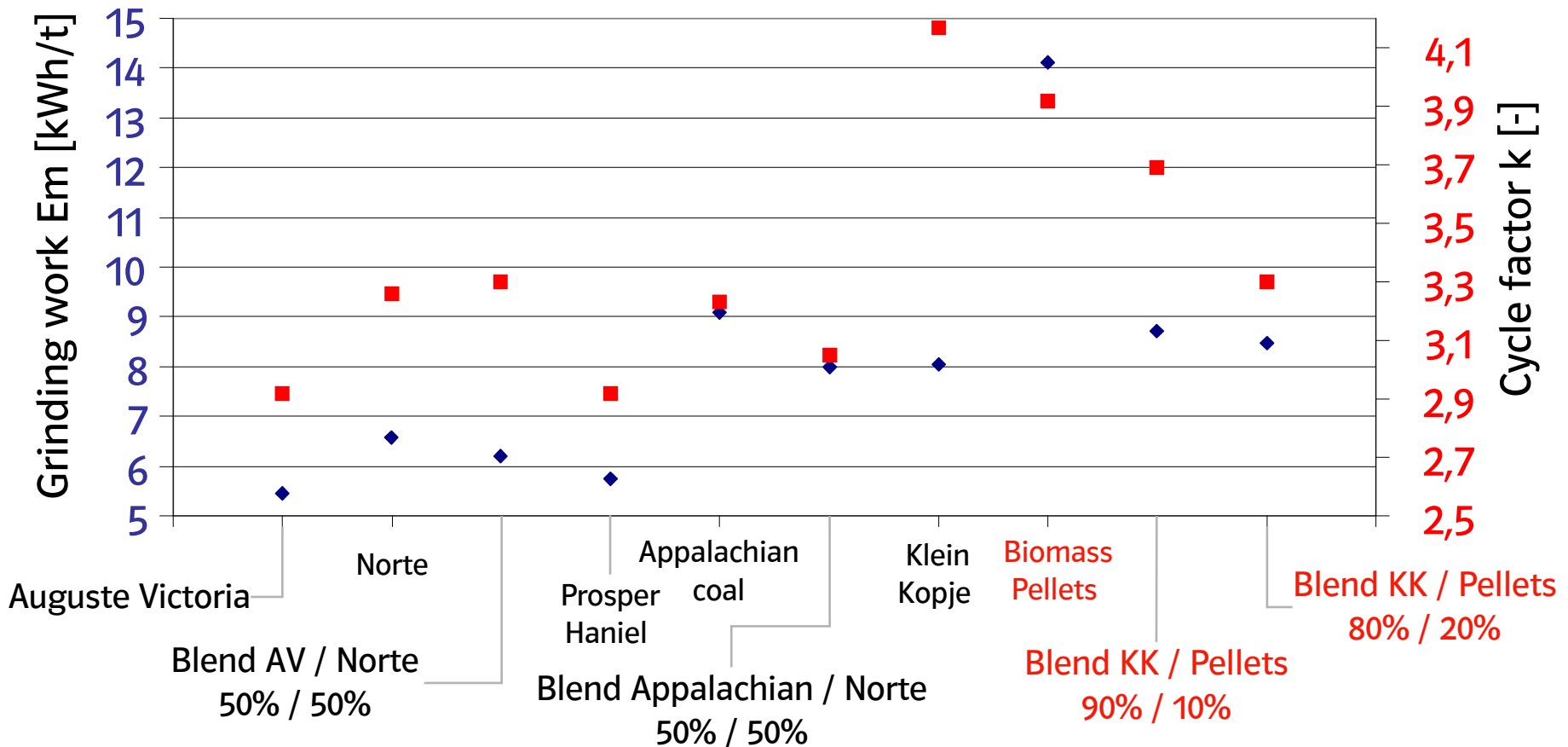
$$\frac{\text{power consumption}}{\text{sample quantity}}$$



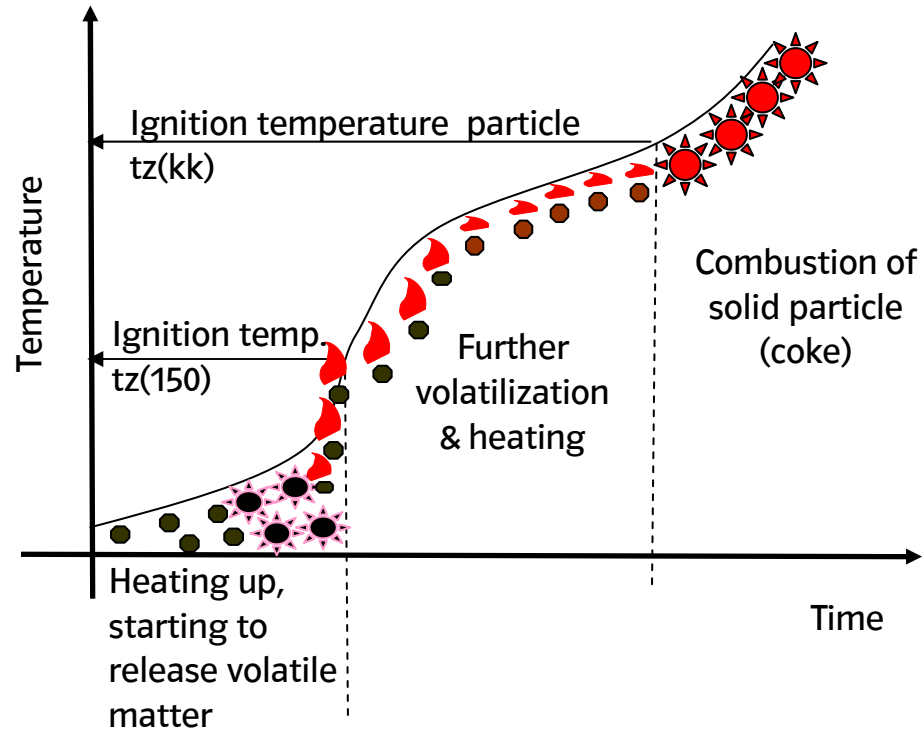
Cycle factor  $k$  [-]

$$\frac{M (\text{coarse material})}{M (\text{pulverized material})}$$

## Testing Grindability - Results



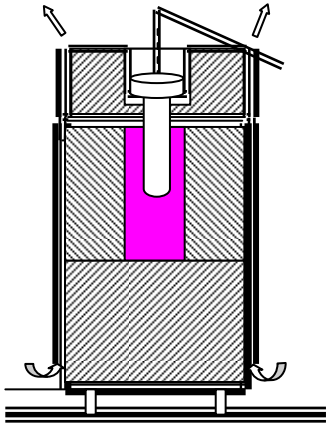
# Testing Ignition- and Combustion behavior



$$ZWZ = \frac{N_{Z500}}{t_{Z150}} \left[ \frac{kJ}{kgCoal^{\circ}C} \right]$$

## Testing Ignition Potential

- Determination of  $Nz_{500}$



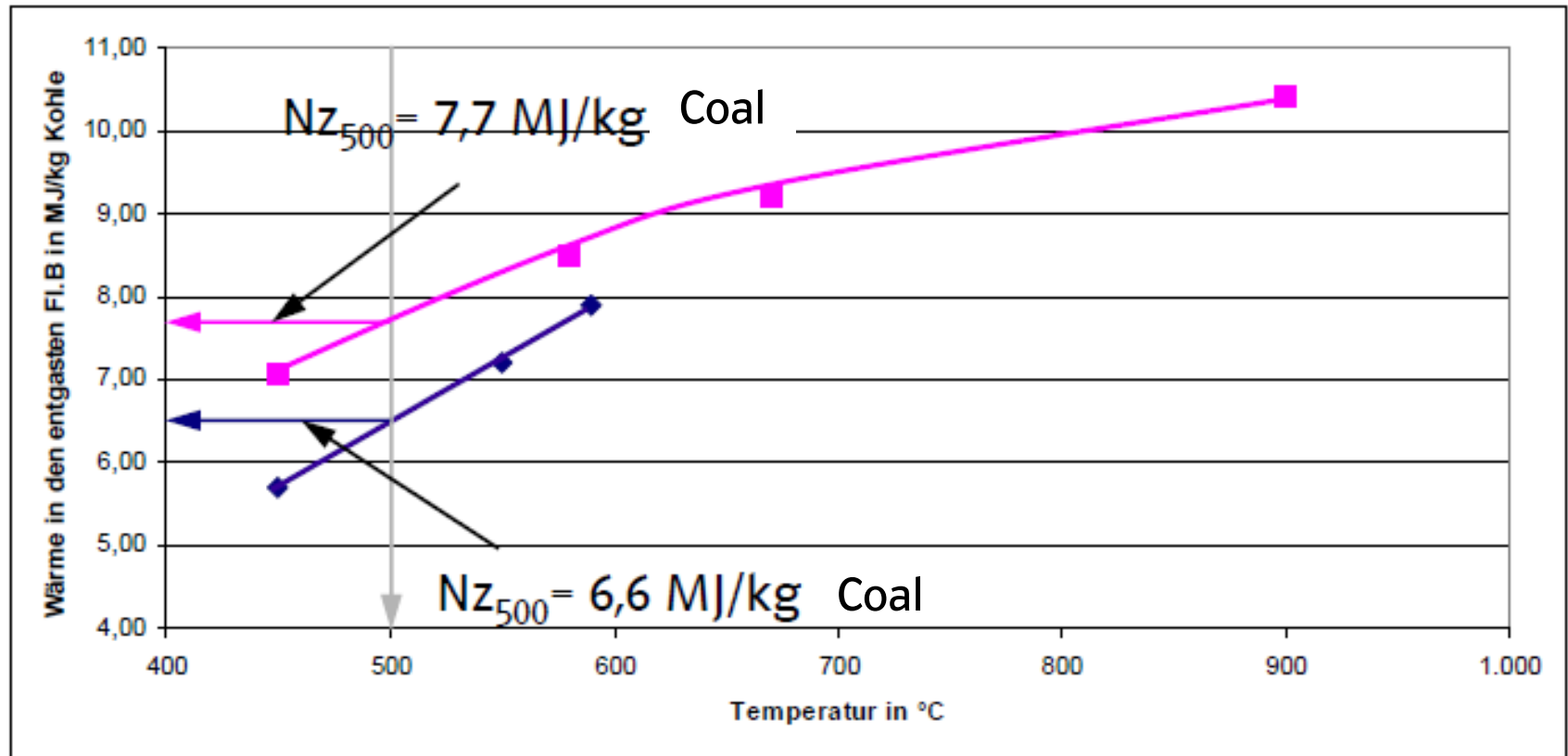
Degasification  
alembic



# Testing Ignition Potential

$$ZWZ = \frac{N_{Z500}}{t_{Z150}} \left[ \frac{kJ}{kgCoal^{\circ}C} \right]$$

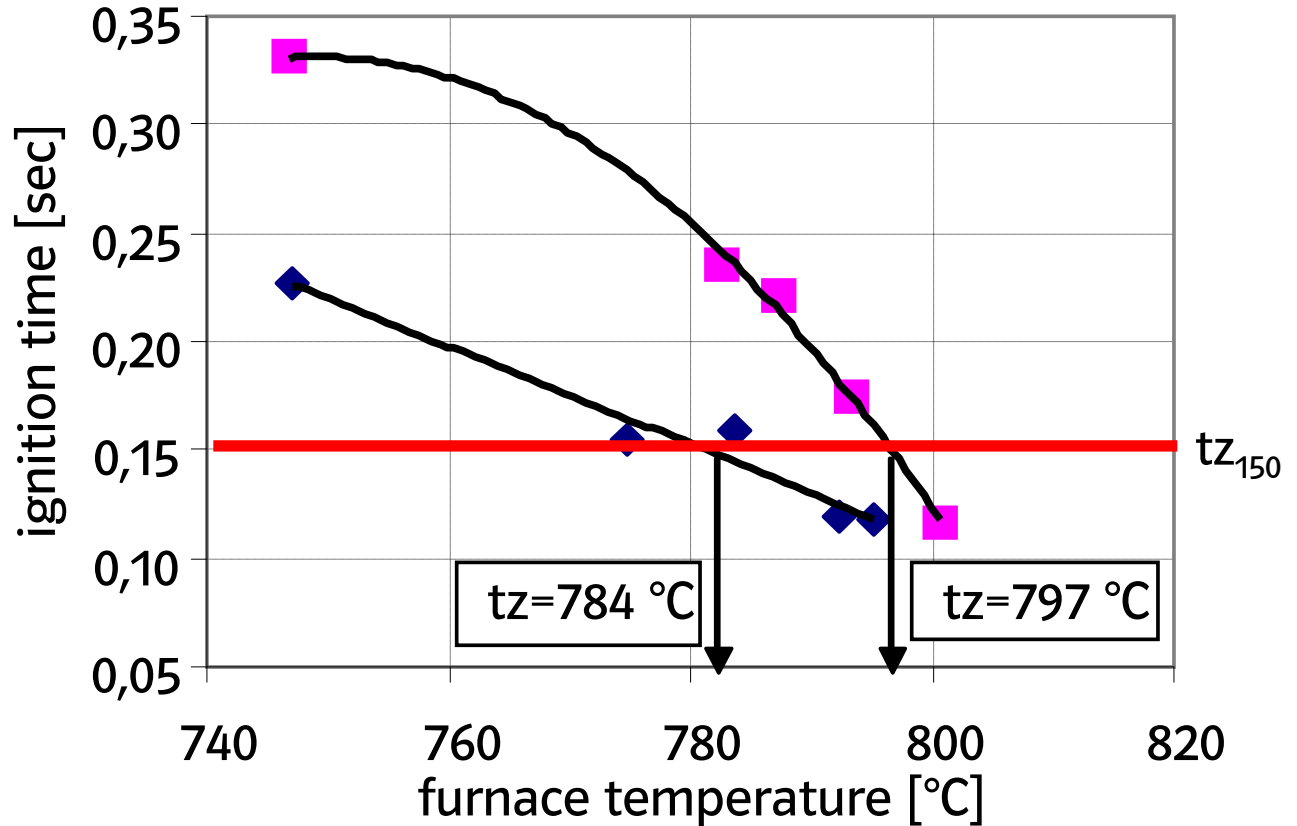
- Determination of  $N_{Z500}$



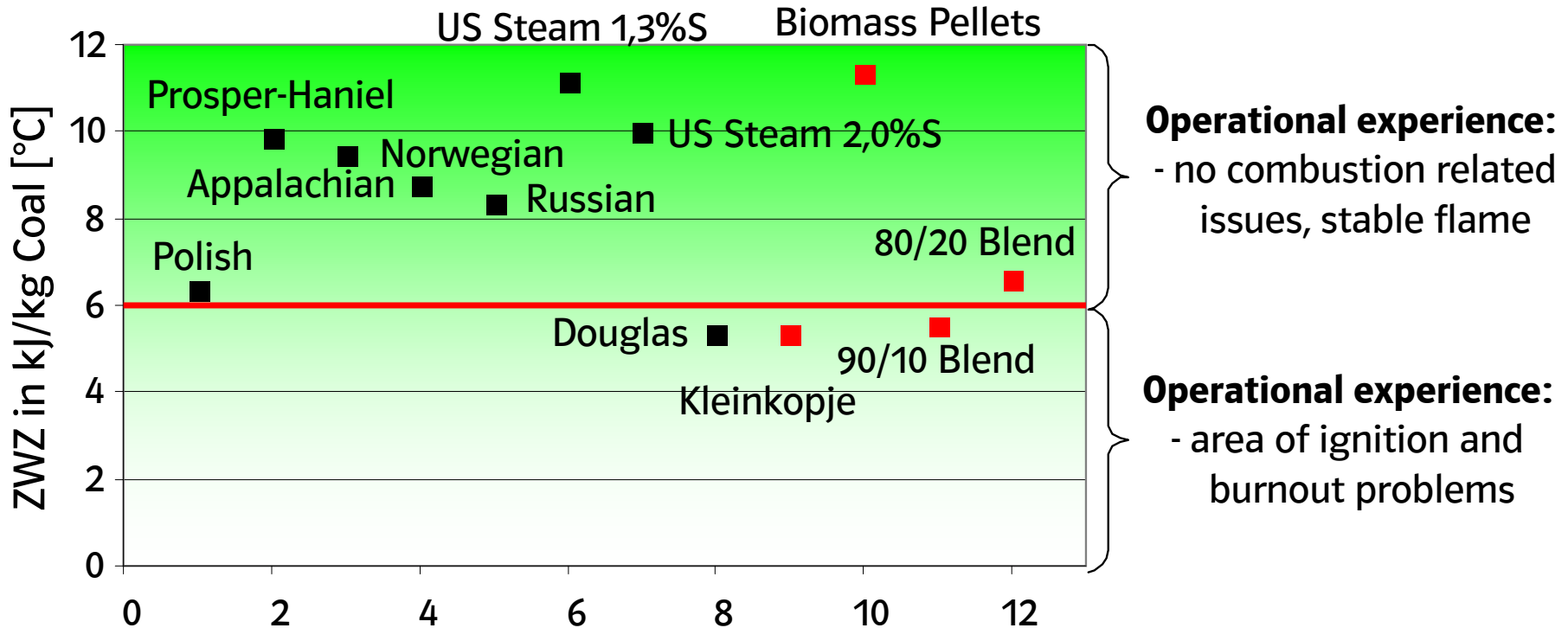
# Testing Combustion Behavior

- Determination of  $t_{z_{150}}$

$$ZWZ = \frac{N_{Z500}}{t_{Z150}} \left[ \frac{kJ}{kgCoal^{\circ}C} \right]$$



# Ignitability Parameter



## Summary

- Biomass Co-firing is a proven technology for feeding 5%wt ... 20%wt
- Feeding rates of 40%wt – 50%wt seem feasible for selected plants
- Bottle necks of the specific plant and selected biomass must be thoroughly investigated and well known
- Power plant process has to be upgraded for intensive utilization of Co-firing



## Summary

- Mental barriers for some biomasses may occur
- Complexity of producing power increases
- New analytical methods / diagnosis tools are needed
- If you know what you are doing, Co-Firing can be beneficial
  - Economically
  - Emission wise ( $\text{CO}_2$ , S, ...)
  - Combustion behavior

