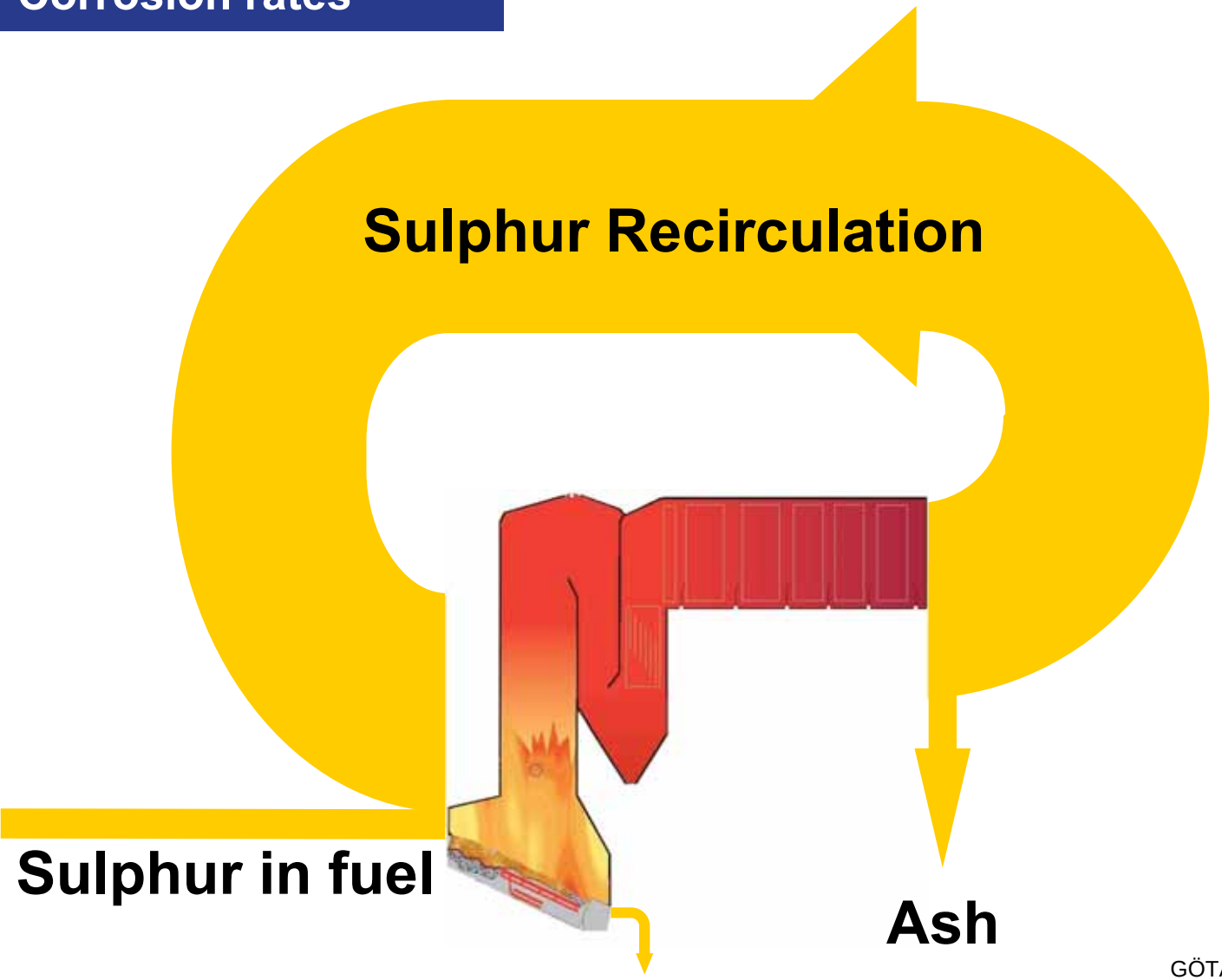
GÖTAVERKEN MILJÖ

Sulphur Recirculation for reducing corrosion and increasing electrical efficiency in WtE boilers

Dr. Sven Andersson

Götaverken Miljö AB, Sweden
– a Babcock & Wilcox Vølund company

- Operating principles
- Full-scale operation
- Ashes and deposits
- Emissions
- Corrosion rates

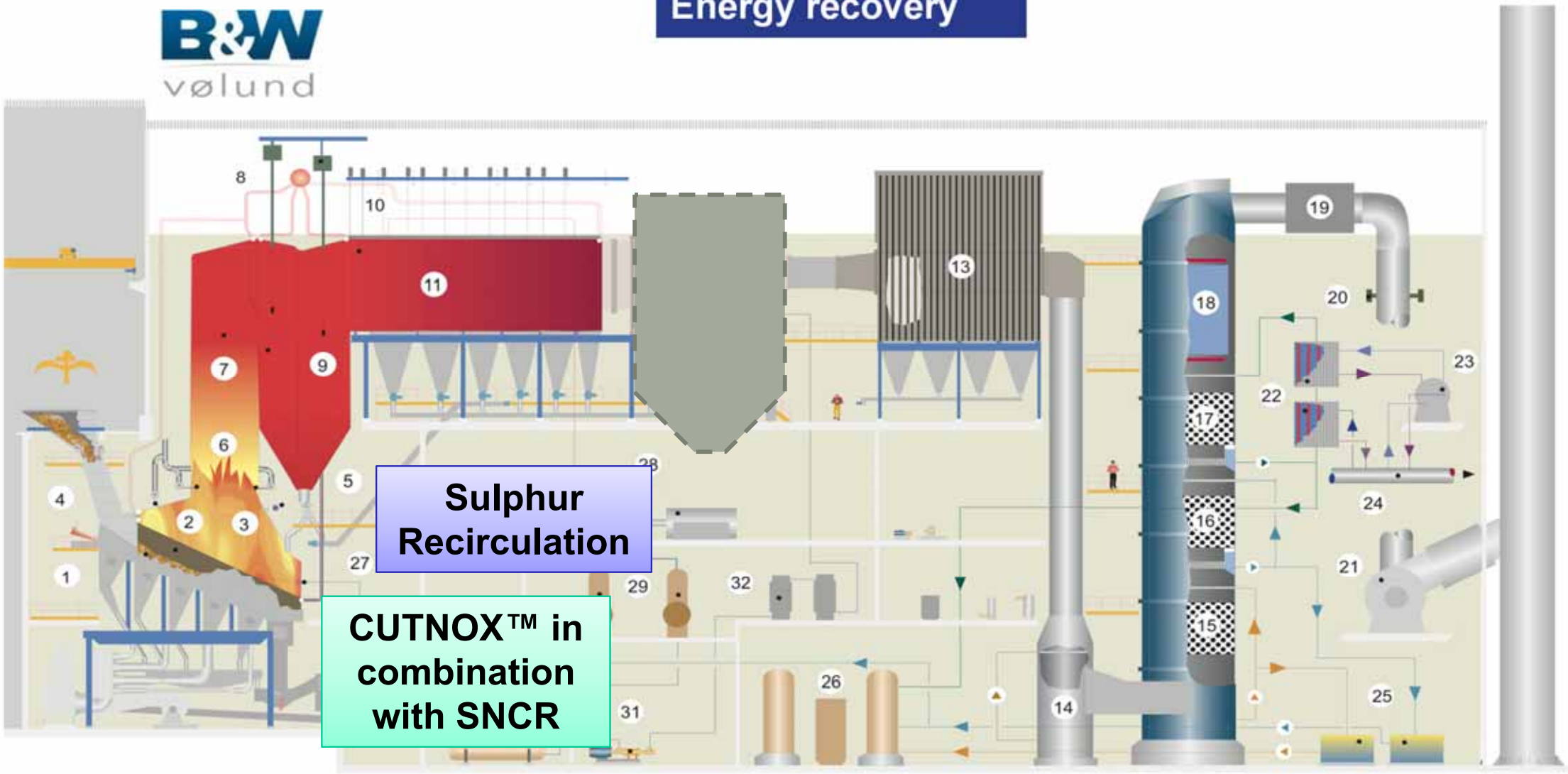


Operating principles
Full-scale installation
NO_x reduction

GÖTAVERKEN MILJÖ

- HCl / SO_2 / NH_3
- Hg
- Dioxins
- NO_x
- Fine particles
- Energy recovery

B&W vølund



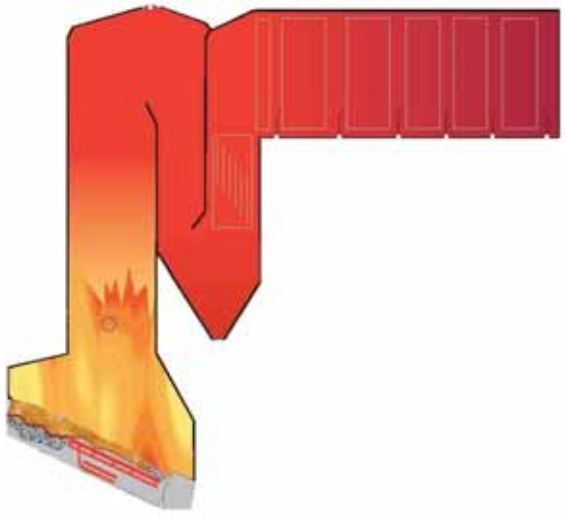
Sulphur Recirculation

CUTNOX™ in combination with SNCR

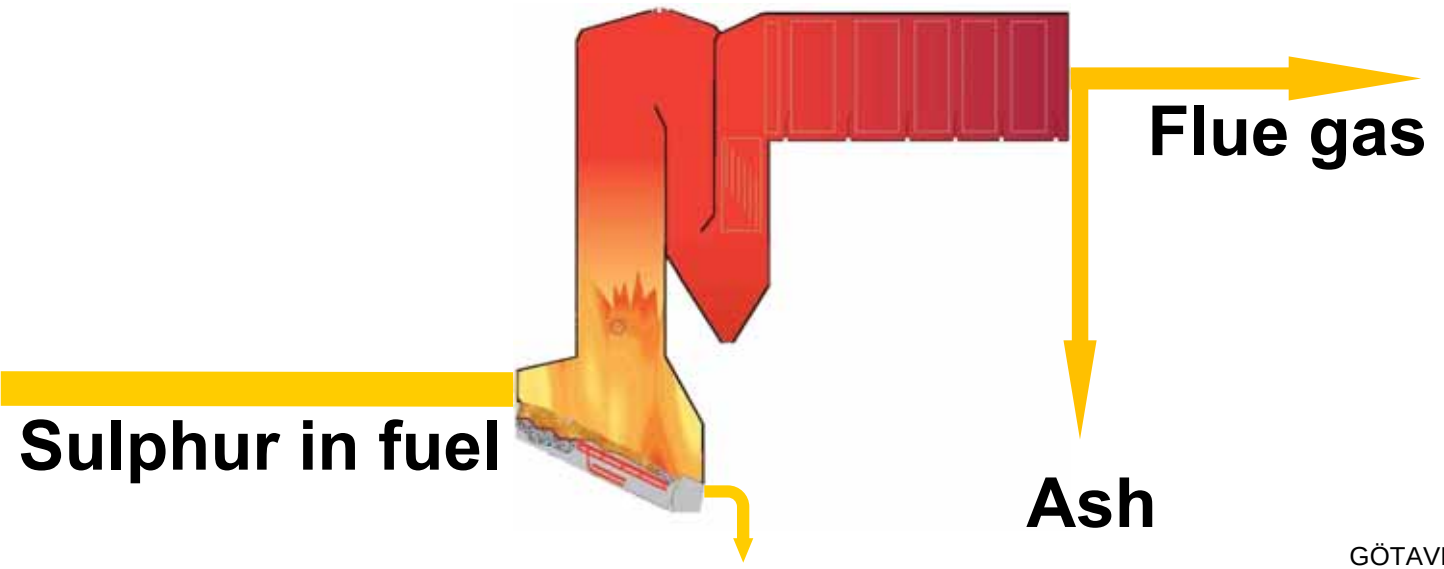
Electricity production in WtE is limited by superheater corrosion

GÖTAVERKEN MILJÖ

Biomass or waste fired boiler



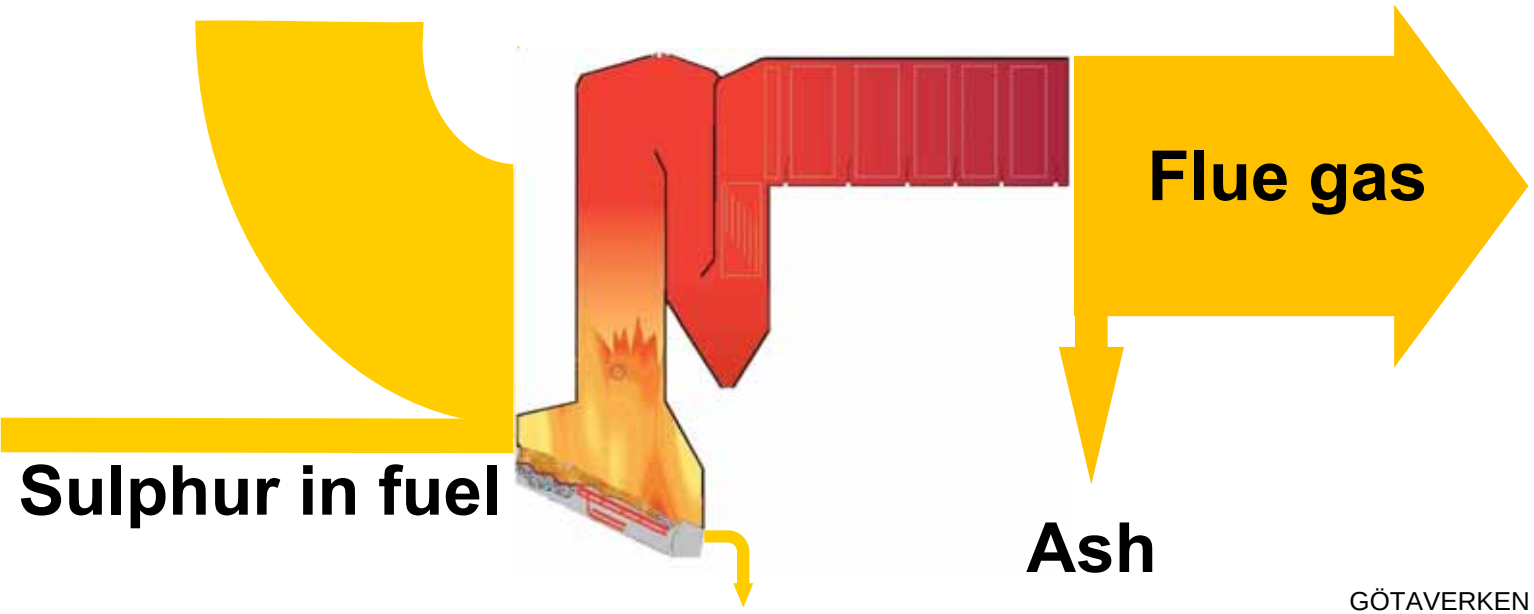
Sulphur mass balance



Sulphur dosage inhibits corrosion

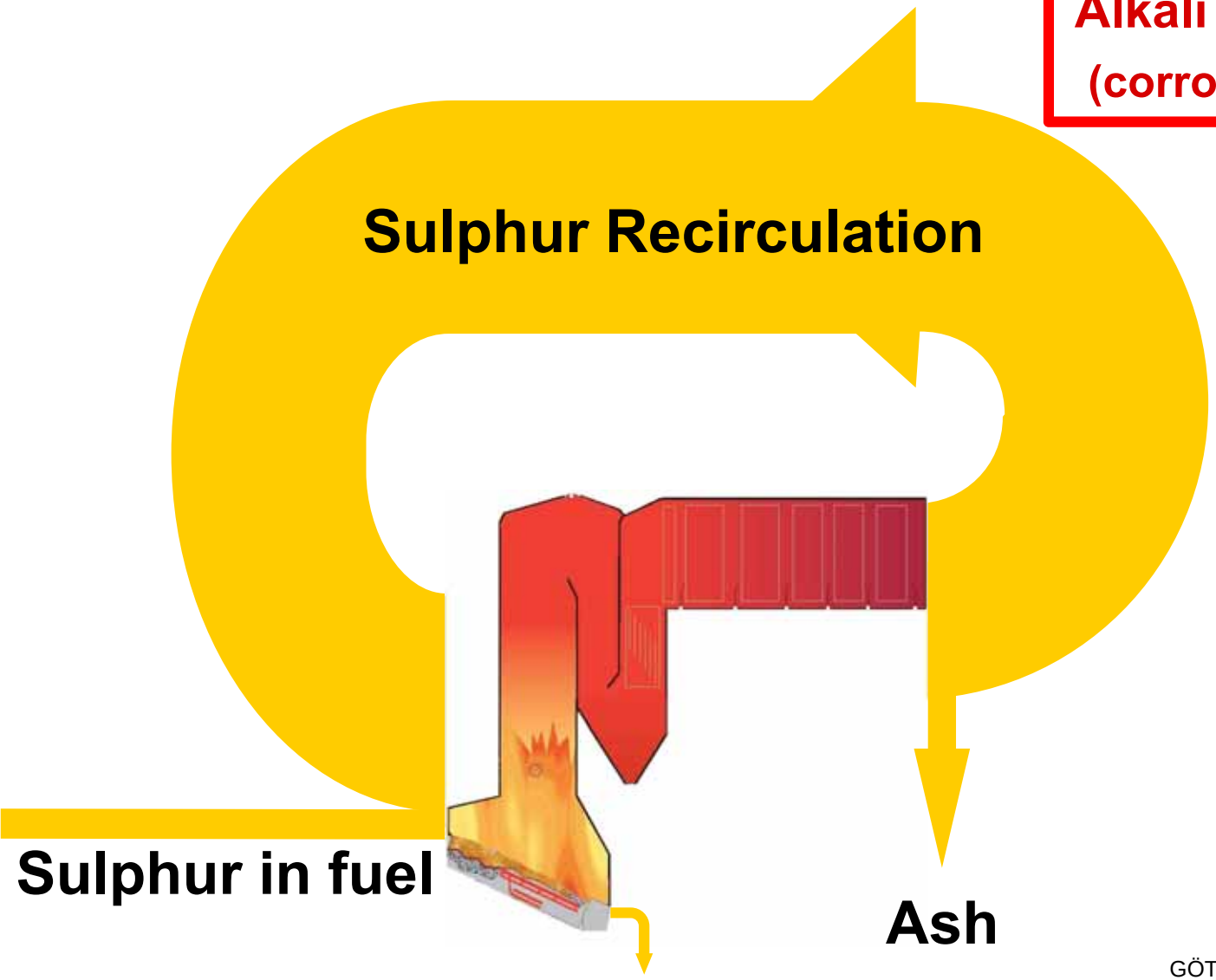
Higher SO_2 concentration:
Alkali chlorides → alkali sulphates
(corrosive) (non corrosive)

Sulphur dosage

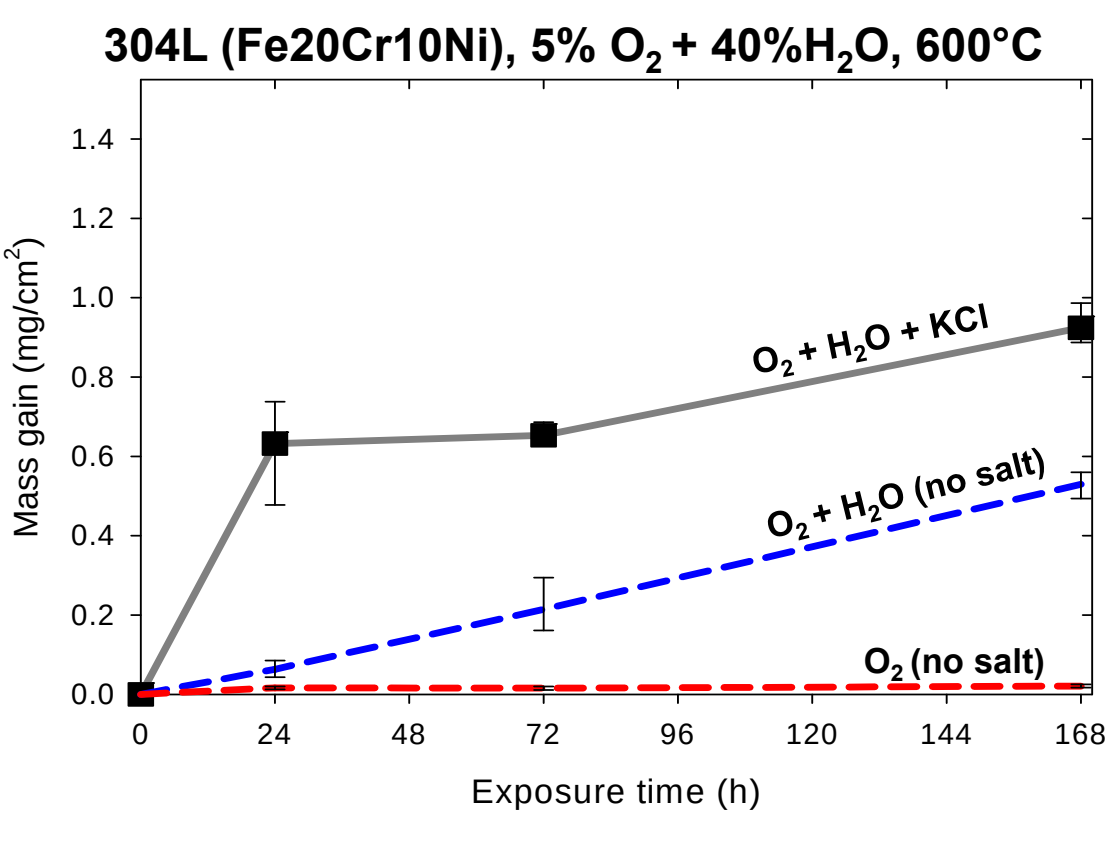


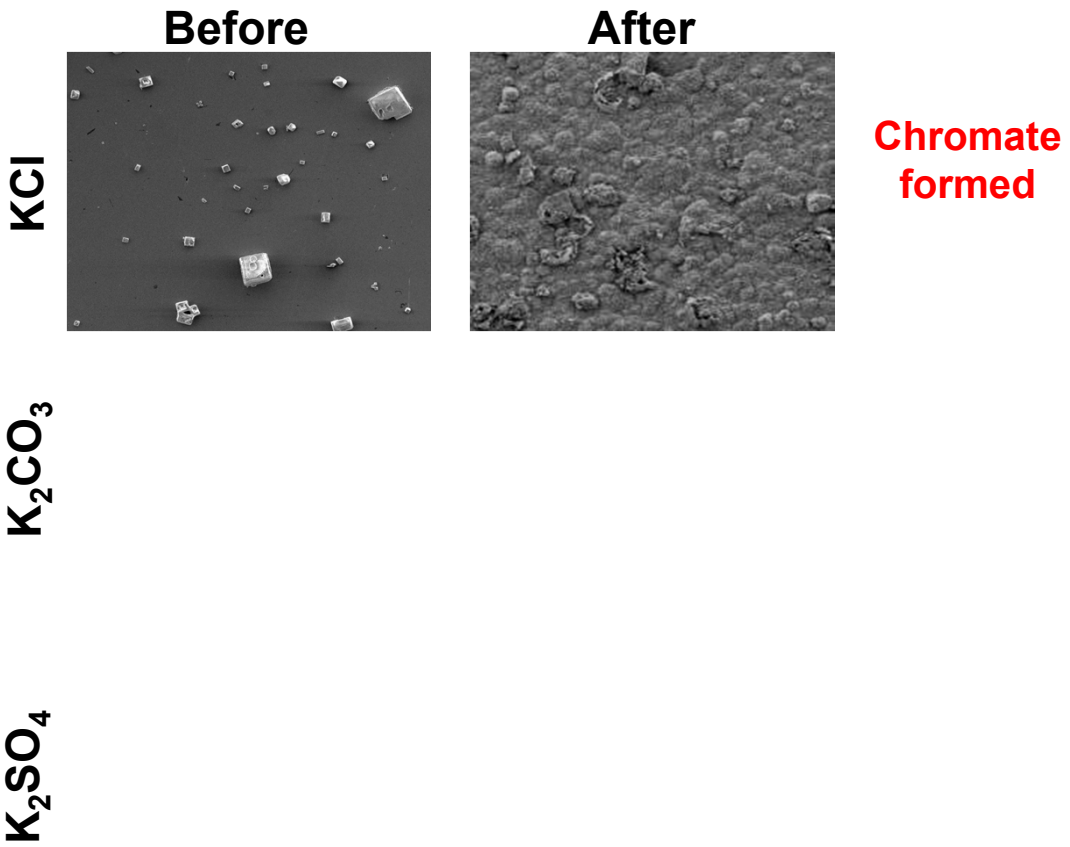
Sulphur Recirculation for High Efficiency, Low Corrosion WtE

Higher SO_2 concentration:
Alkali chlorides → alkali sulphates
(corrosive) (non corrosive)



The effect of chromium depletion on chromia forming steels

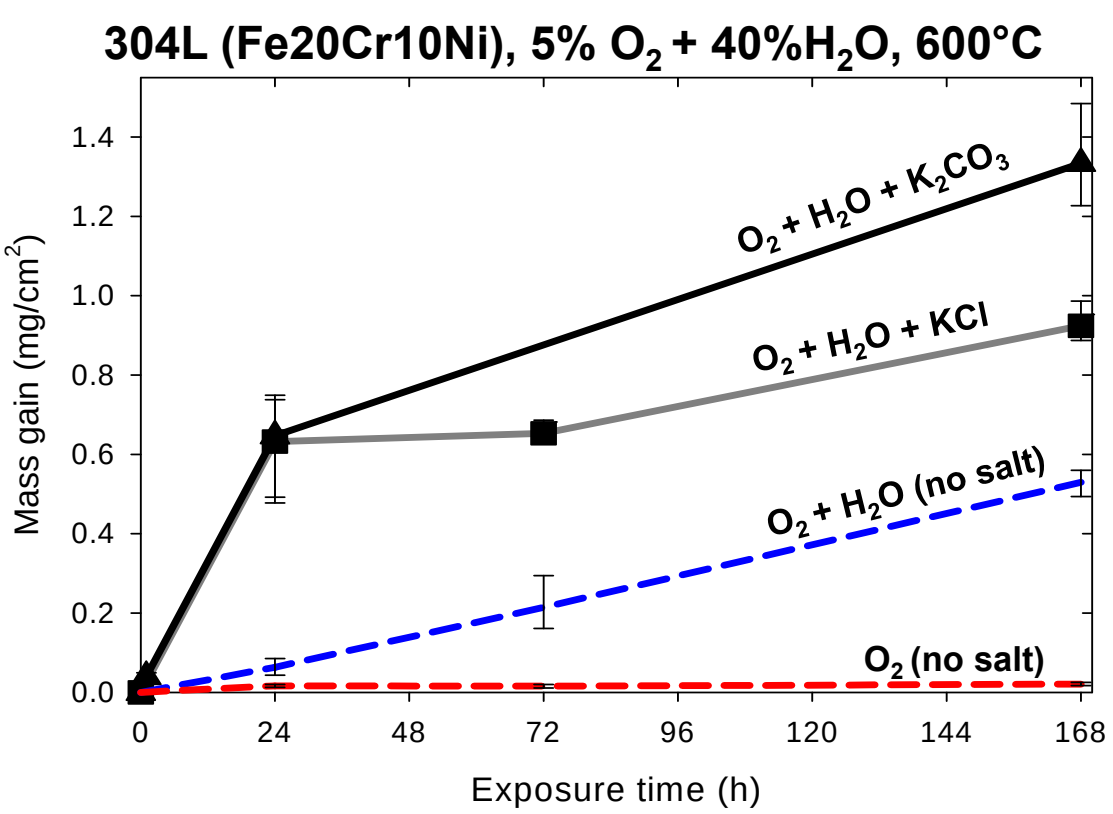


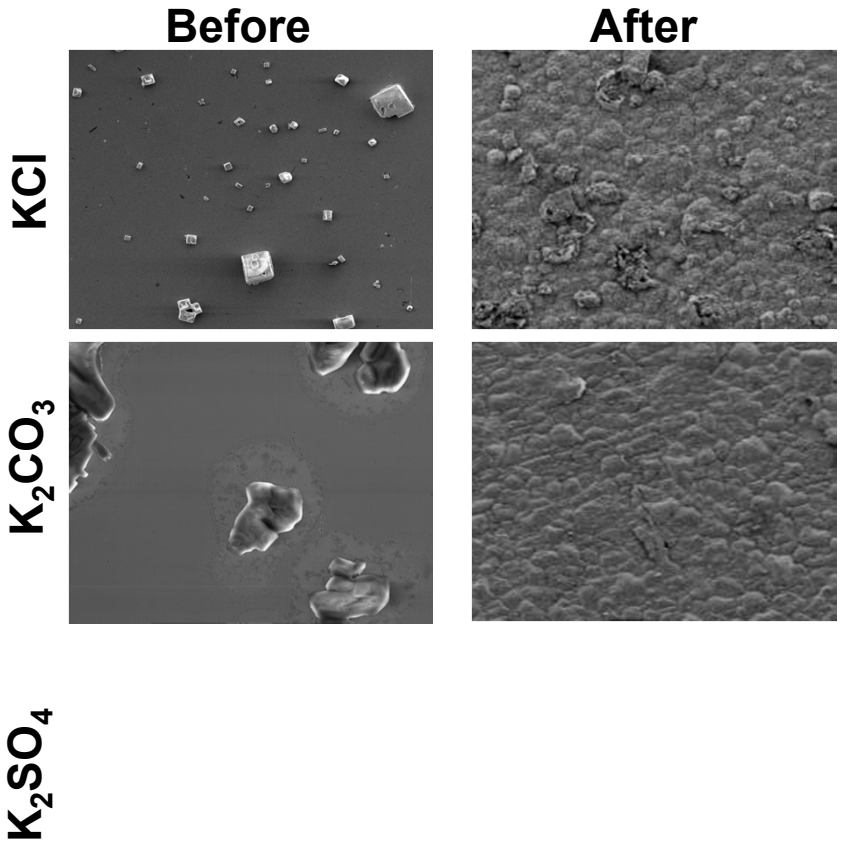


$$(Cr,Fe)_2O_3 \xrightarrow{O_2 + H_2O + KCl} Fe_2O_3 + K_2CrO_4 + HCl$$

Pettersson, J., Folkeson, N., Johansson, L.-G., Svensson, J.-E., *The Effects of KCl, K_2SO_4, and K_2CO_3 on the High Temperature Corrosion of a 304-Type Austenitic Stainless Steel.* Oxidation of Metals, 2011. **76**(1): p. 93-109.

The effect of chromium depletion on chromia forming steels

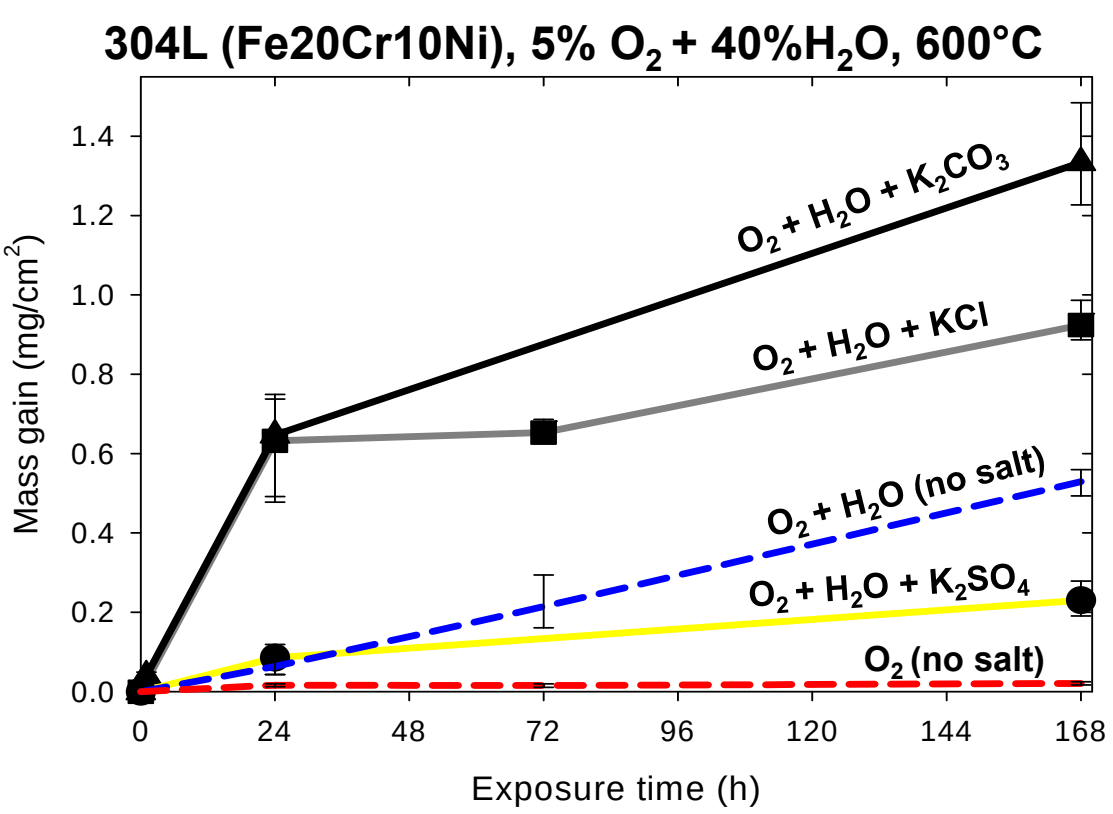


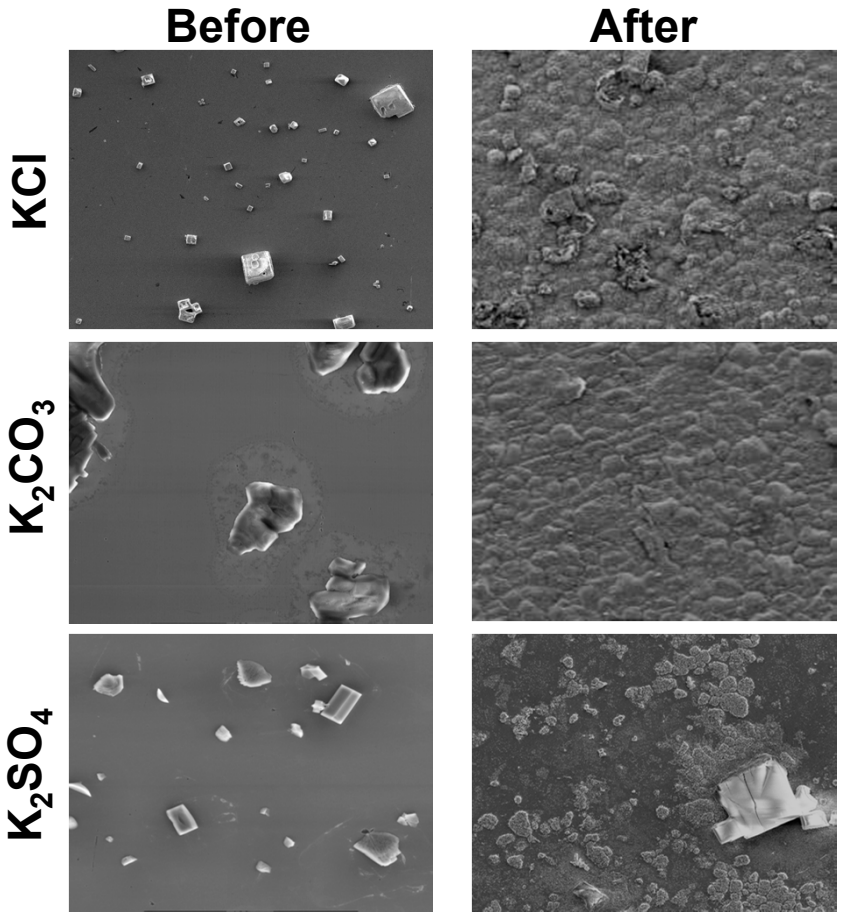


$$(Cr,Fe)_2O_3 \xrightarrow{O_2 + H_2O + K_2CO_3} Fe_2O_3 + K_2CrO_4 + CO_2$$

Pettersson, J., Folkeson, N., Johansson, L.-G., Svensson, J.-E., *The Effects of KCl, K_2SO_4, and K_2CO_3 on the High Temperature Corrosion of a 304-Type Austenitic Stainless Steel.* Oxidation of Metals, 2011. **76**(1): p. 93-109.

The effect of chromium depletion on chromia forming steels





$$(Cr,Fe)_2O_3 \xrightarrow{O_2 + H_2O + K_2SO_4} Fe_2O_3 + K_2CrO_4 + SO_2$$

Pettersson, J., Folkeson, N., Johansson, L.-G., Svensson, J.-E., *The Effects of KCl, K_2SO_4, and K_2CO_3 on the High Temperature Corrosion of a 304-Type Austenitic Stainless Steel.* Oxidation of Metals, 2011. **76**(1): p. 93-109.

GÖTAVERKEN MILJÖ

Super-Heaters

SNCR

Dosage

Oil burn.

Grate

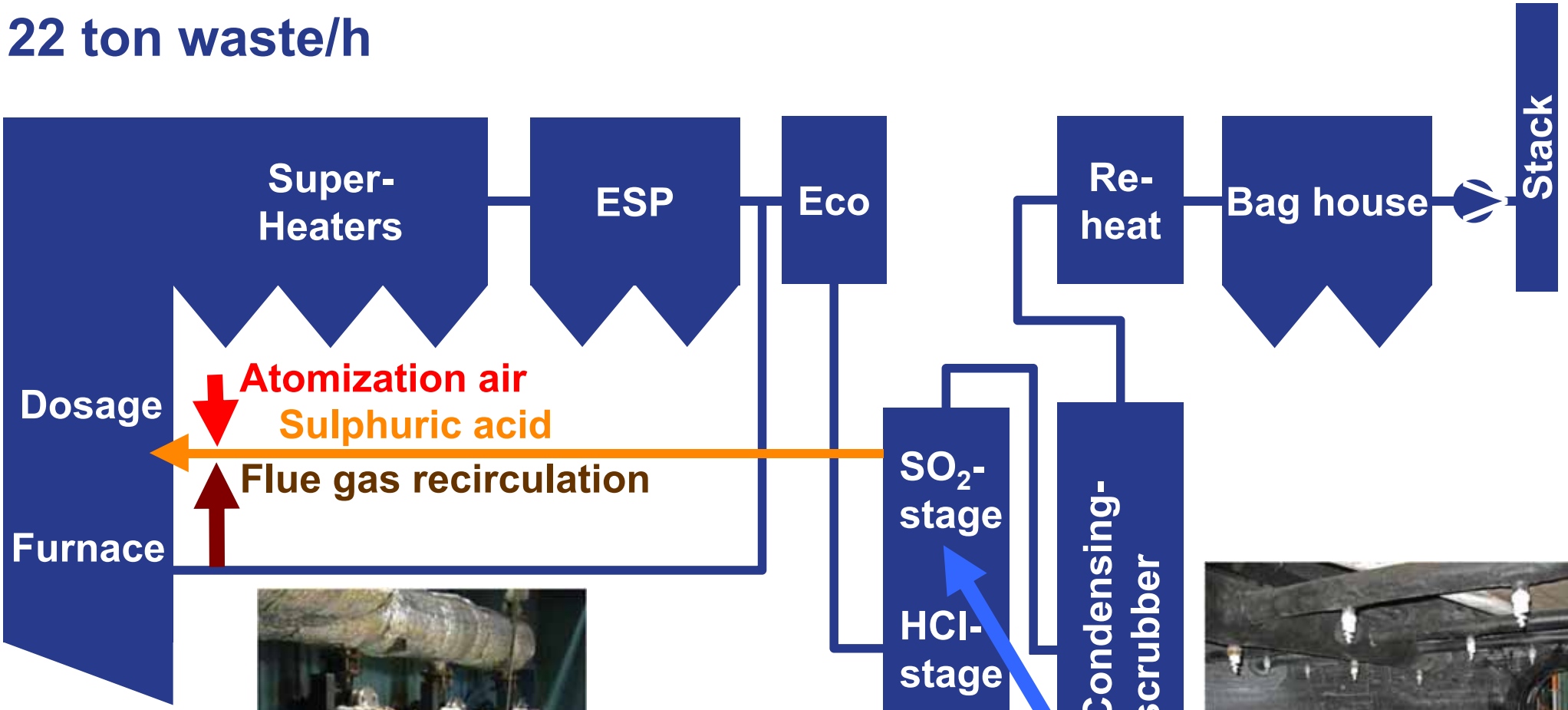
Renova

GARANTERAD ÅTERVINNING

Full-scale tests at Renova P5 (Göteborg)

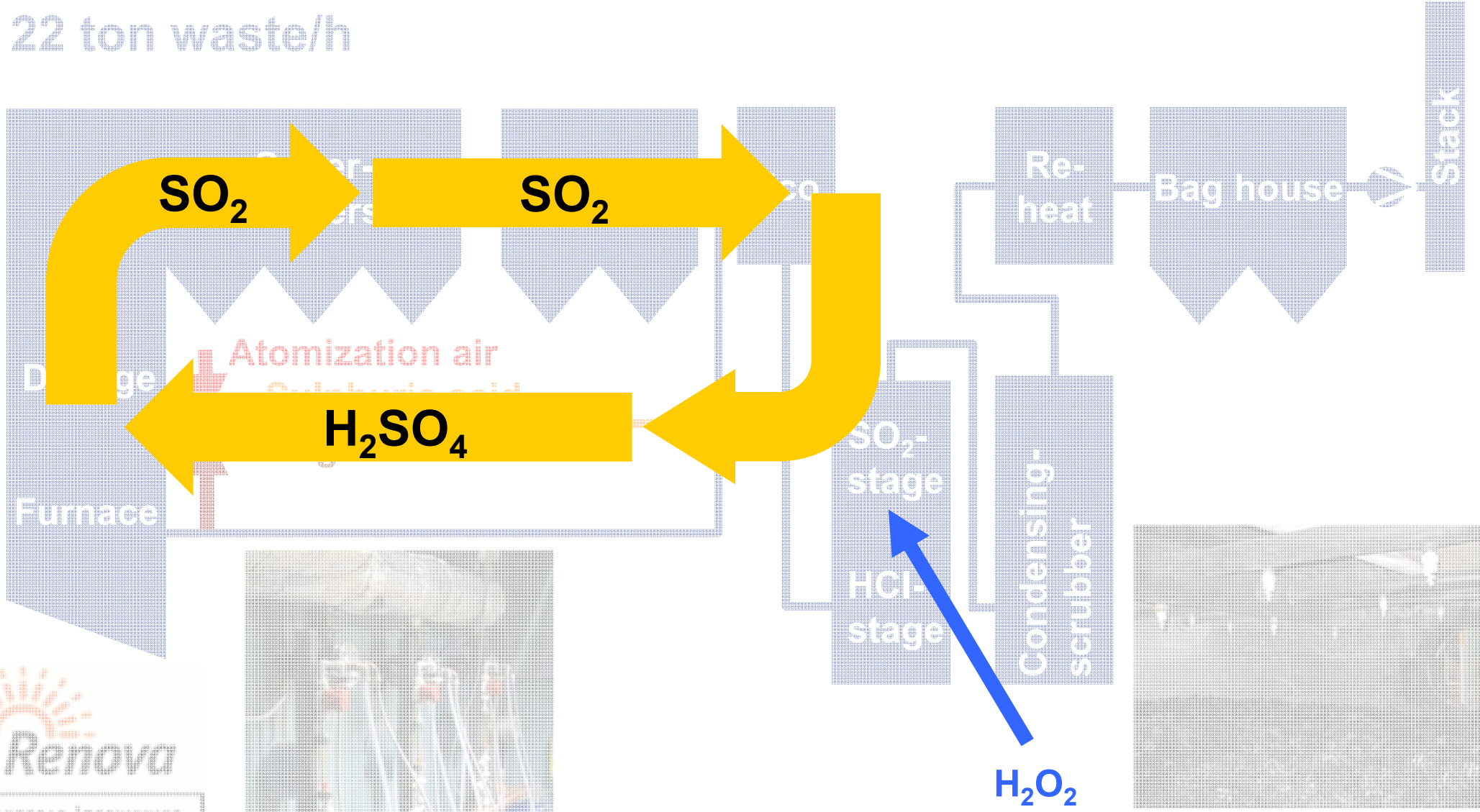
GÖTAVERKEN MILJÖ

22 ton waste/h

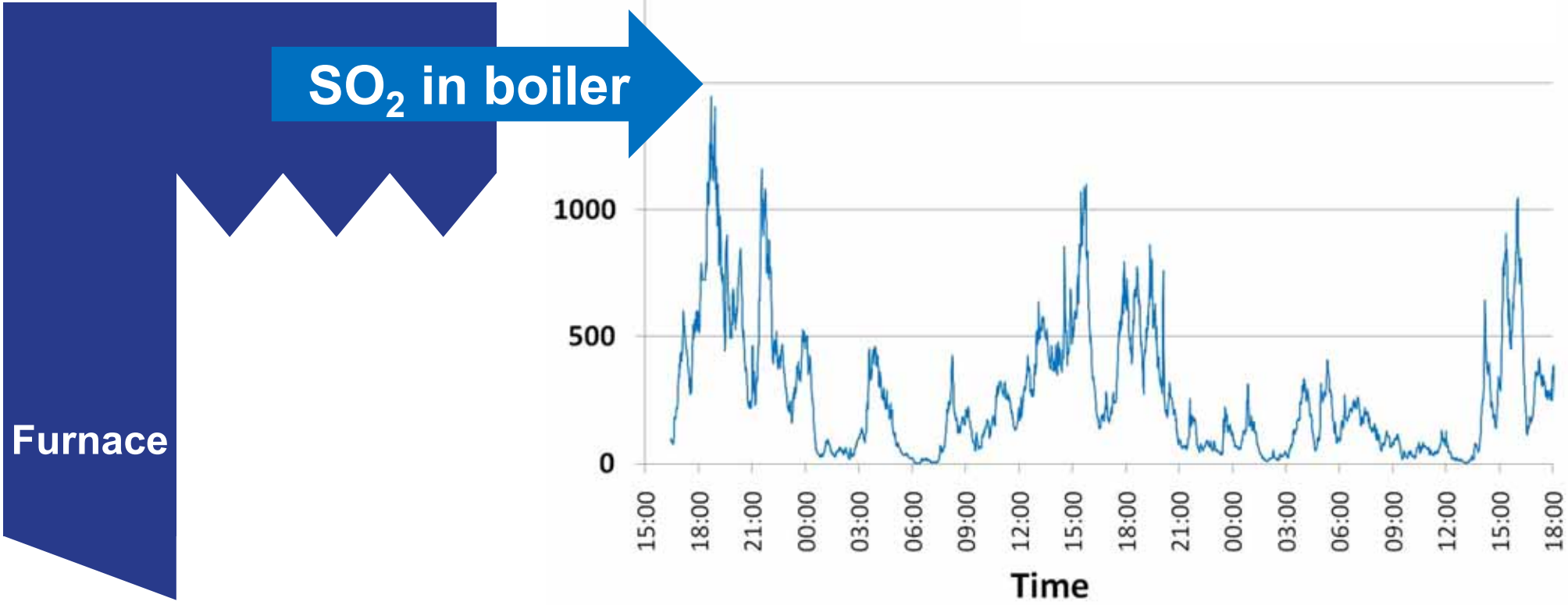


Renova
GARANTERAD ÅTERVINNING

Full-scale tests at Renova P5 (Göteborg)

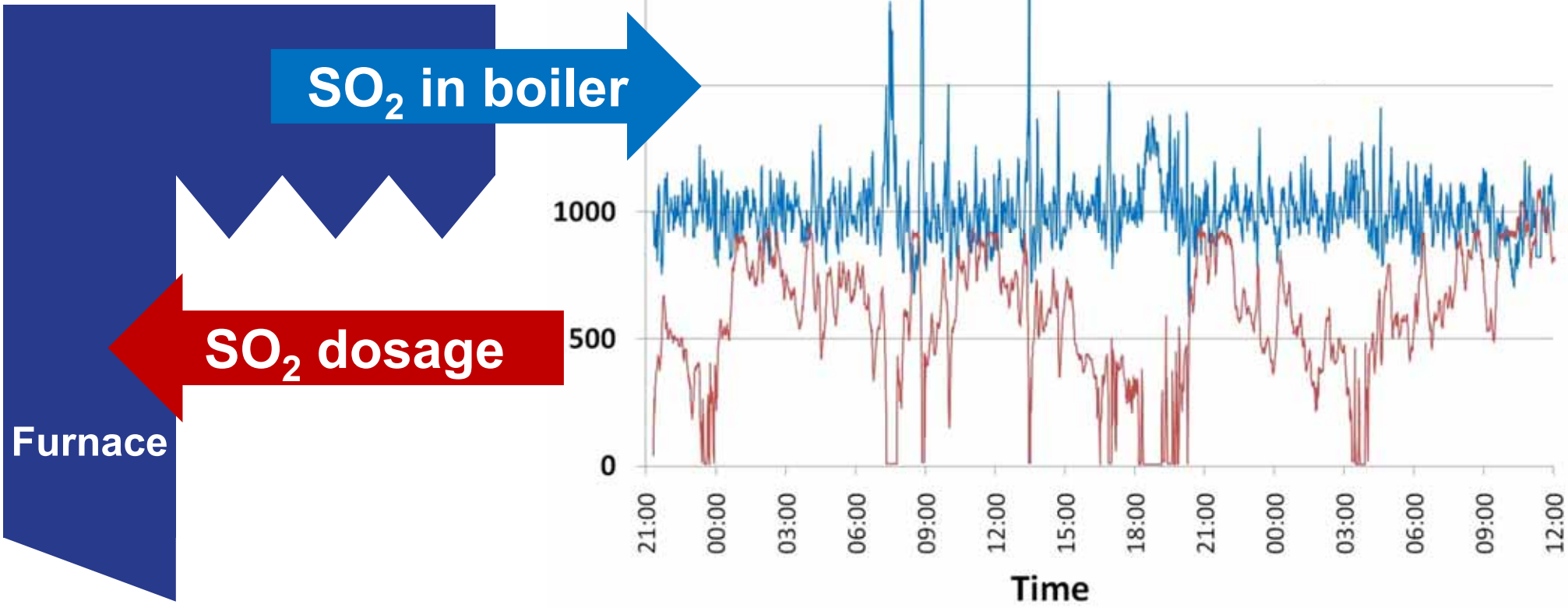


1000 h Reference (normal operation)



1000 h Reference: SO_2 in boiler = 270 mg/m³ (n,dg)

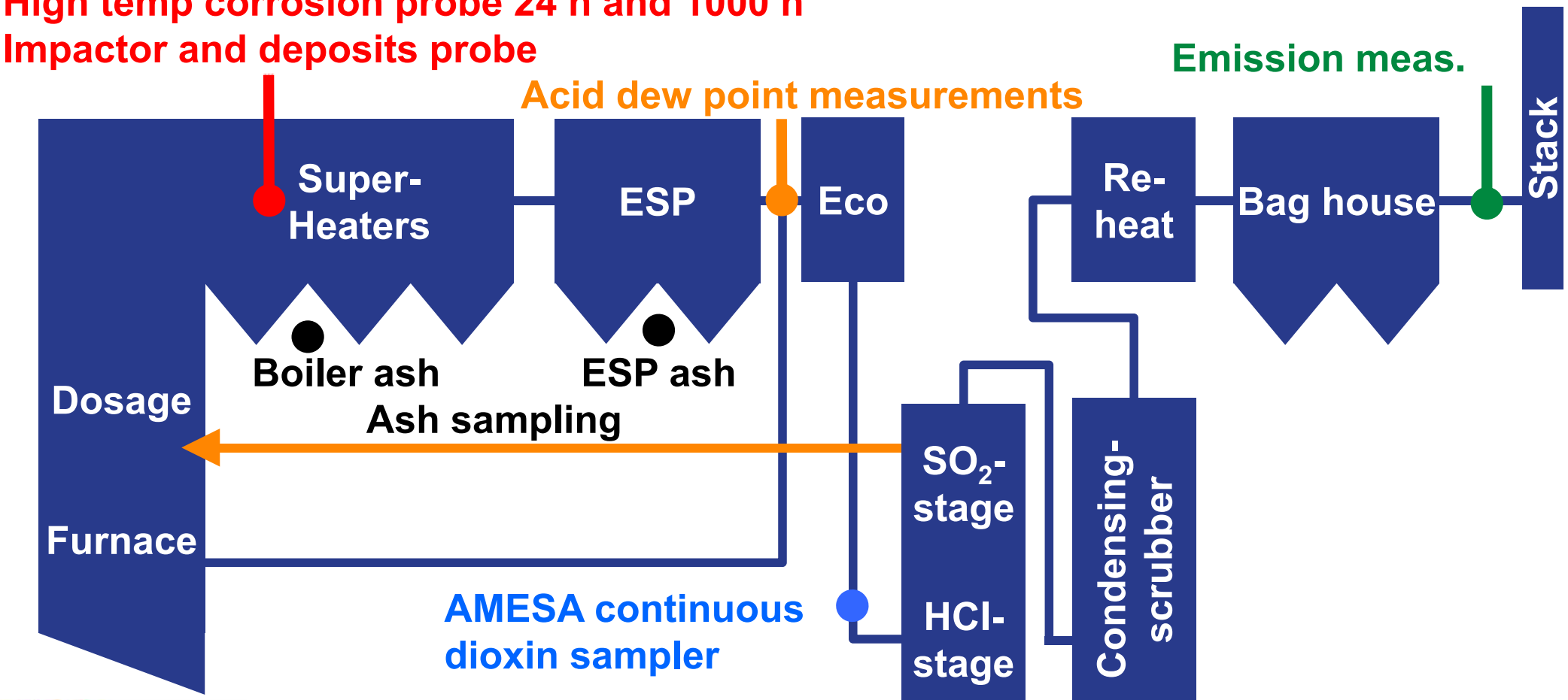
1000 h Recirculation: SO_2-setpoint



1000 h Reference: SO_2 in boiler = 270 mg/m³ (n,dg)

1000 h Recirculation: SO_2 in boiler = 720 mg/m³ (n,dg)

Sampling and measurements



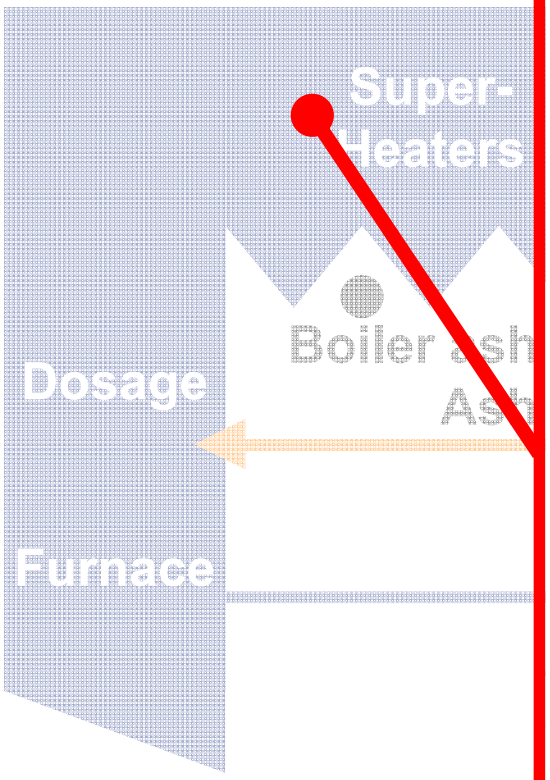
Renova
GARANTERAD ÅTERVINNING

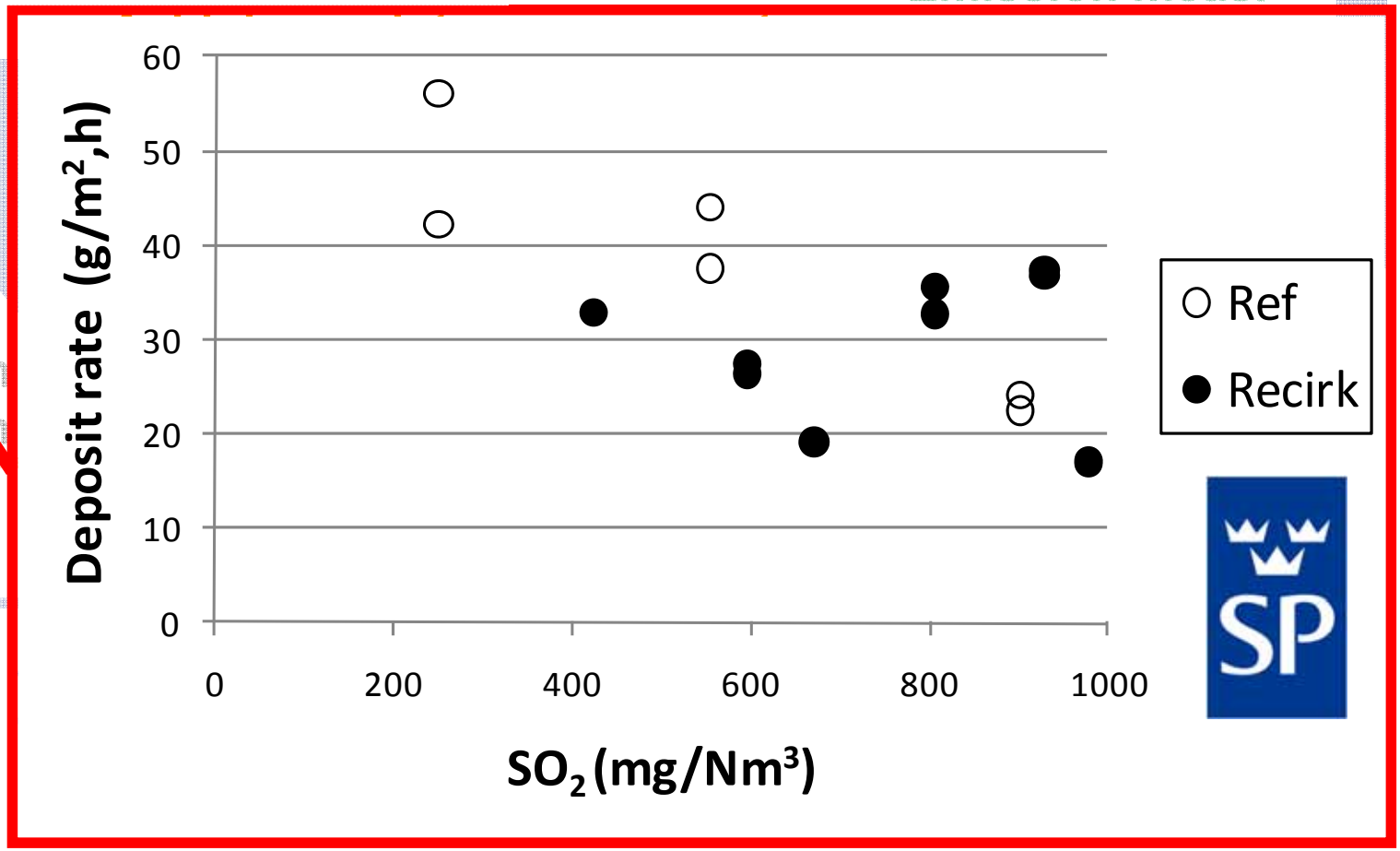
Deposit rate (g/m²,h) decreased with SO_2

High temp corrosion probe 24 h and 1000 h

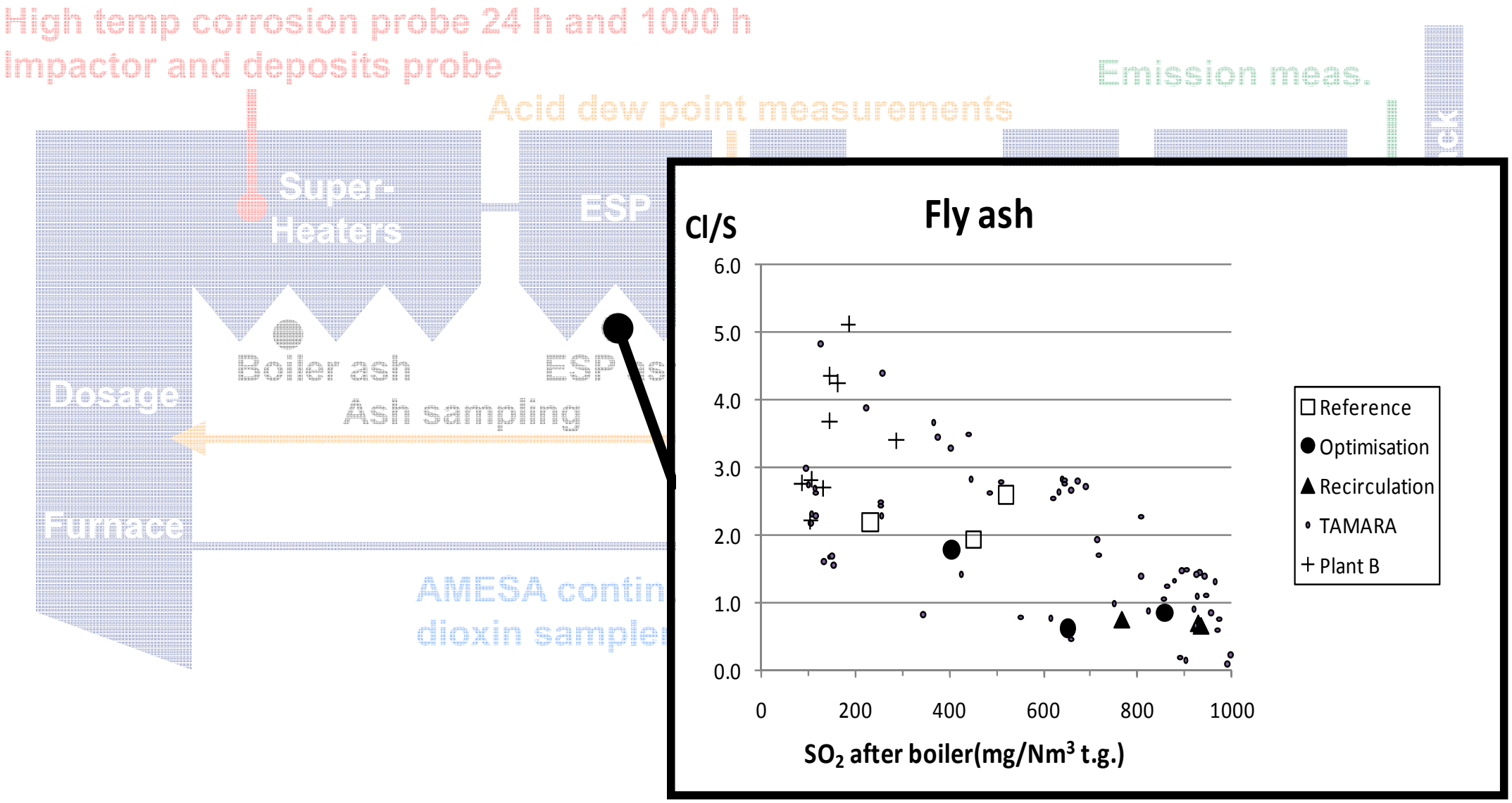
Impactor and **deposits probe**

Emission meas.





Fly ash Cl/S vs SO_2 from 3 different plants



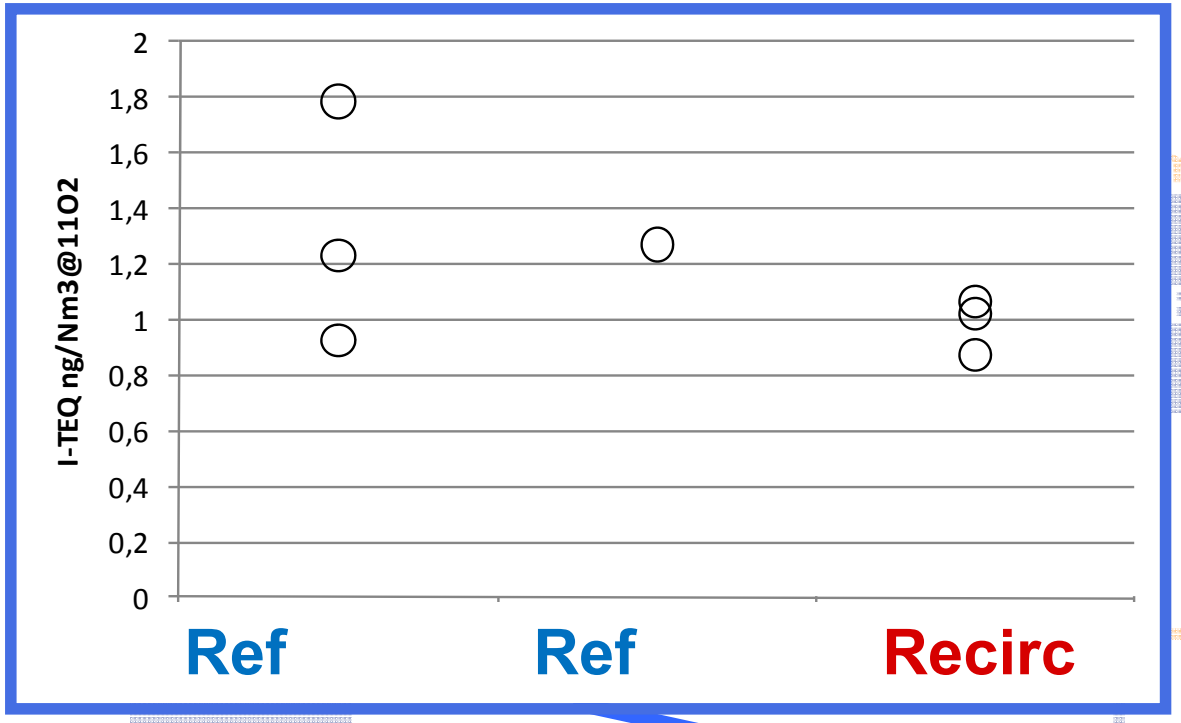
Acid Dew point Temperature (ADT)

Lancom 200
Acid Dewpoint Monitor

Result: No measurable ADT

Detection limit: 110-120°C

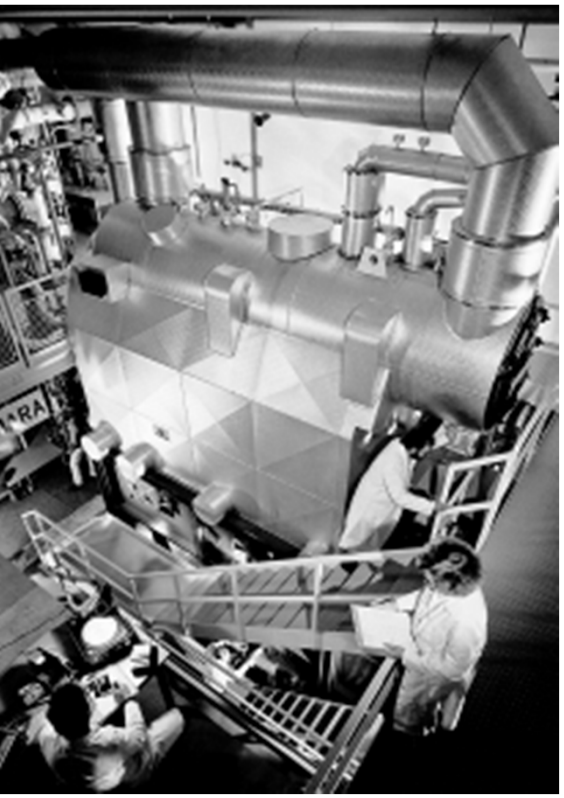
Dioxins in the flue gas: ¼ less

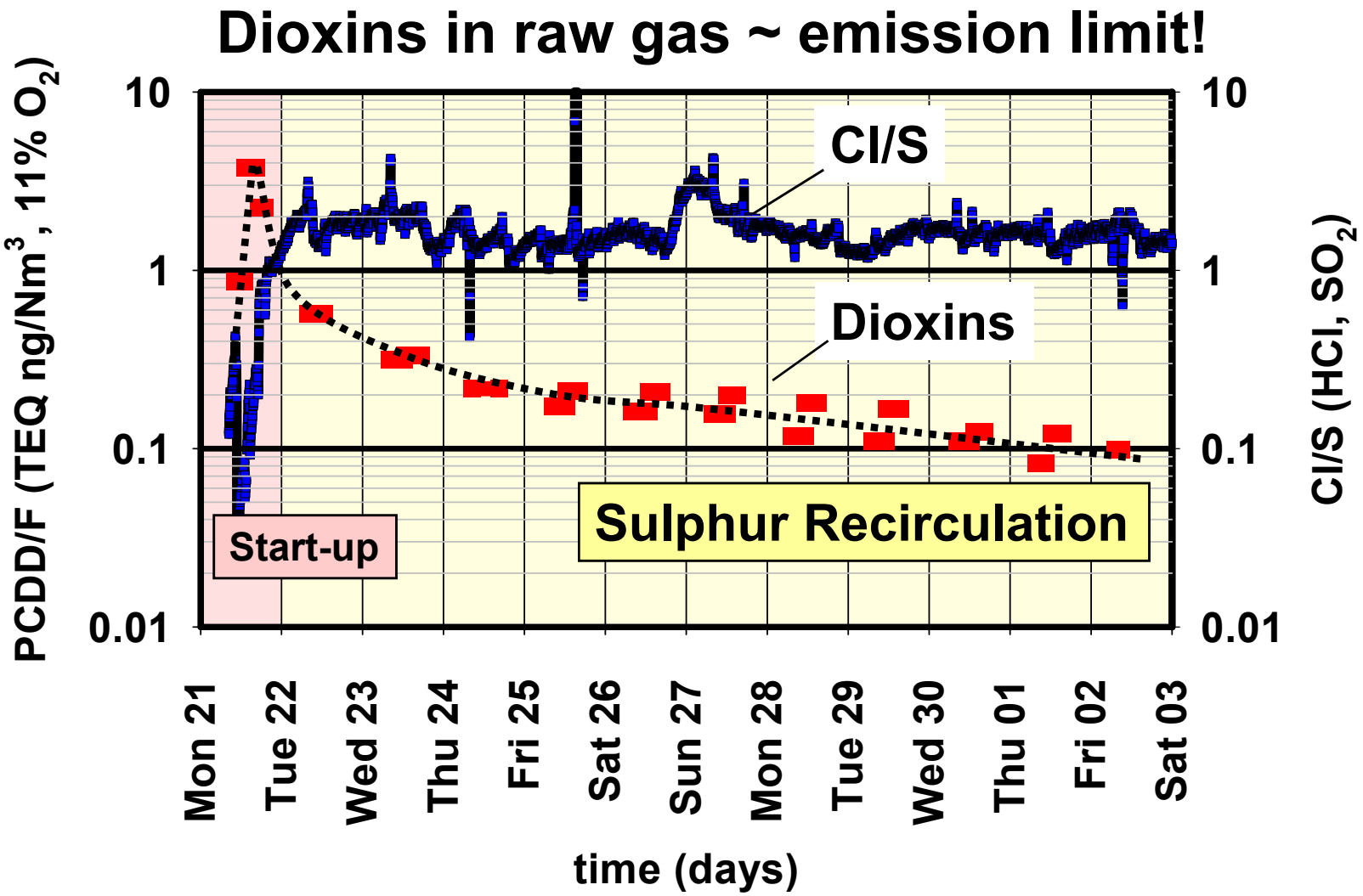


AMESA continuous dioxin sampler

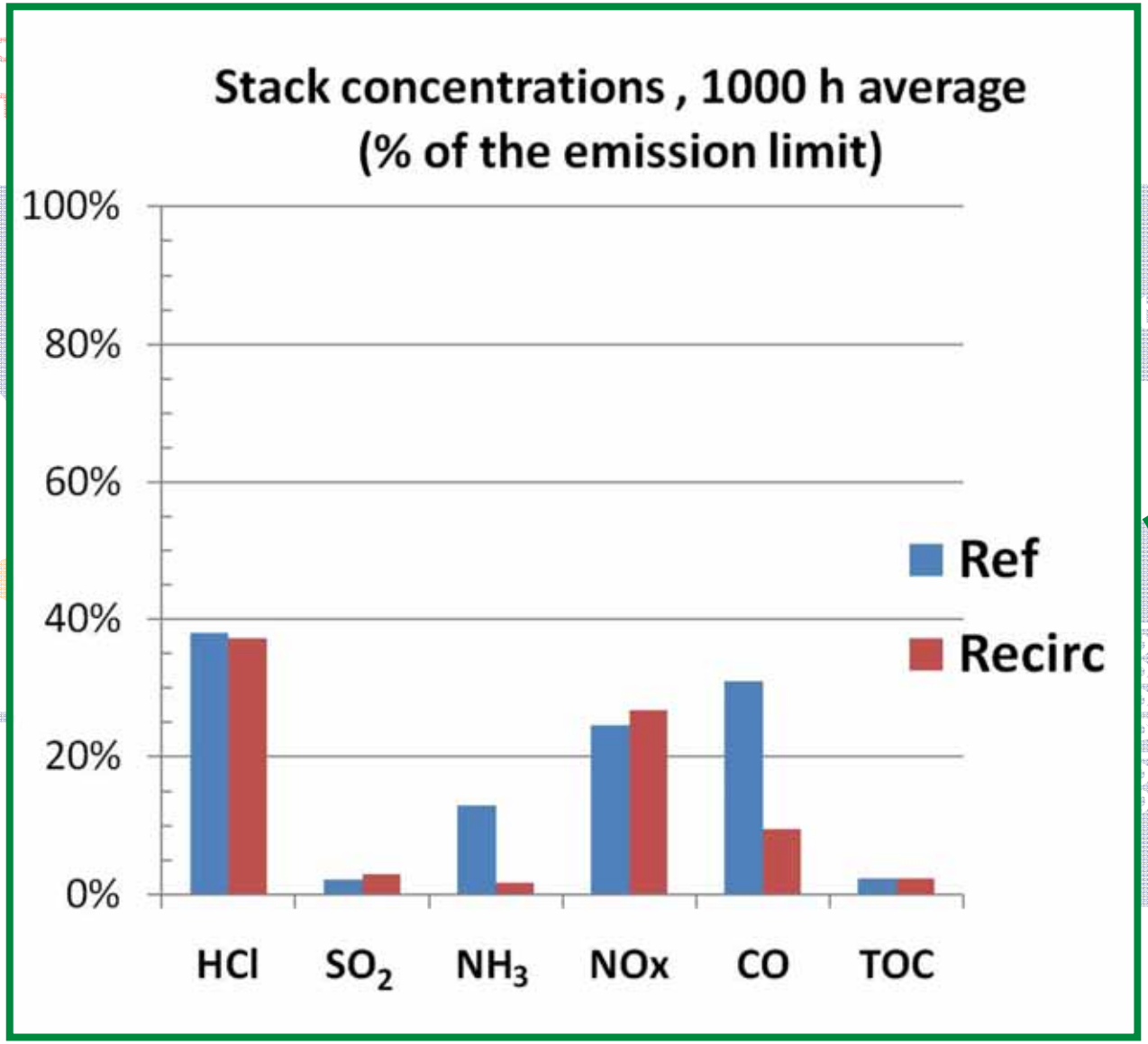
Pilot tests at KIT – Dioxin reduction

Karlsruhe Institute of Technology



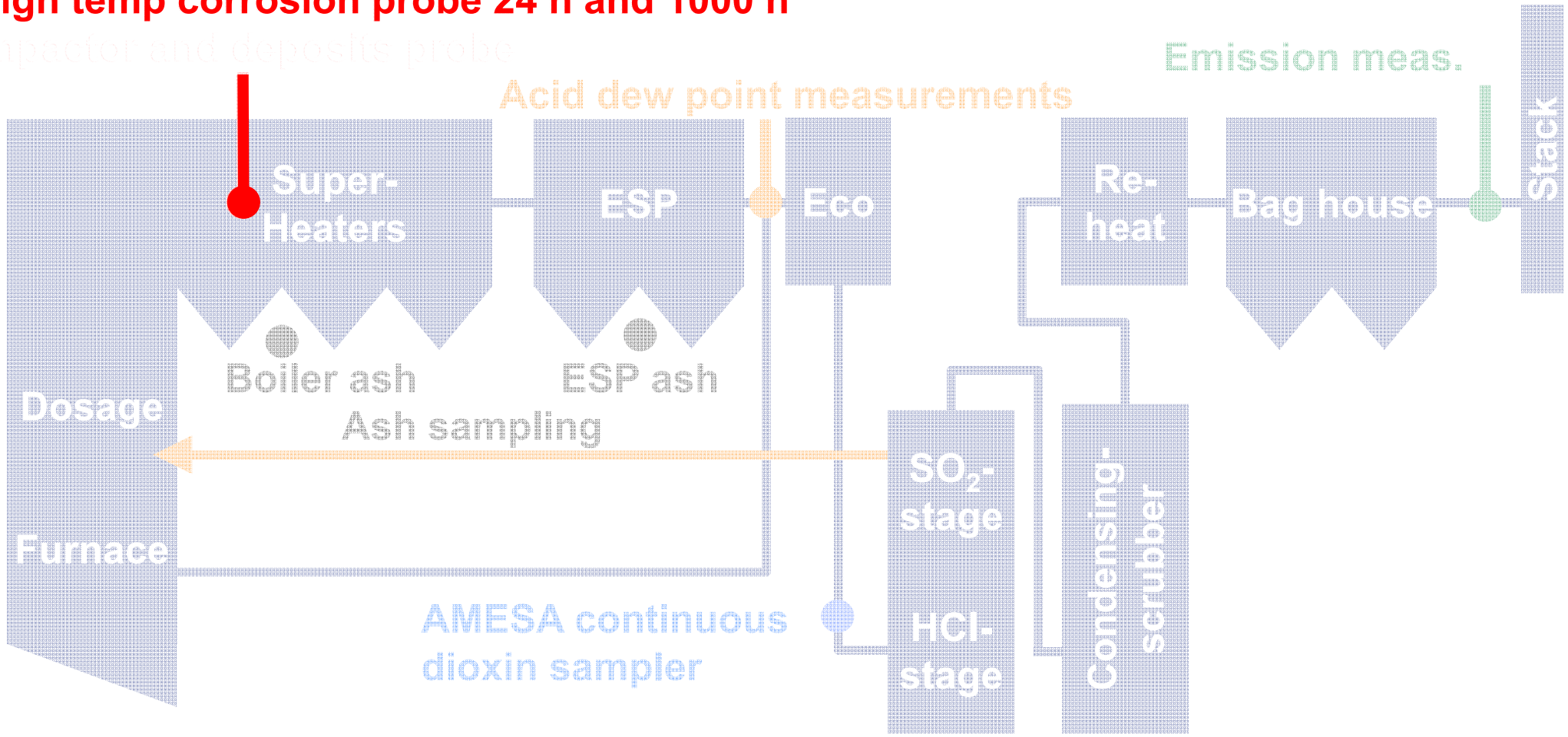


Stack values (% of Emission limit)

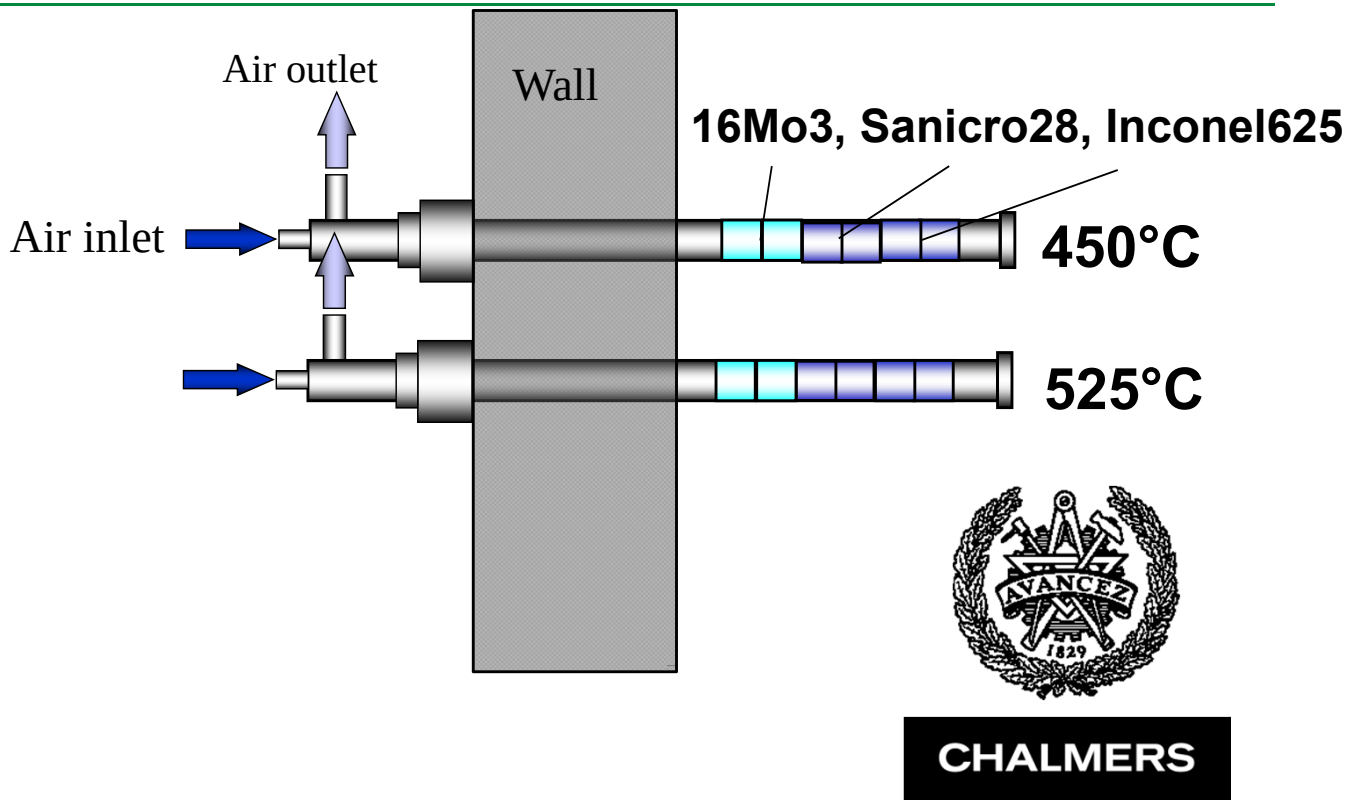


Corrosion probes in the superheater position

High temp corrosion probe 24 h and 1000 h

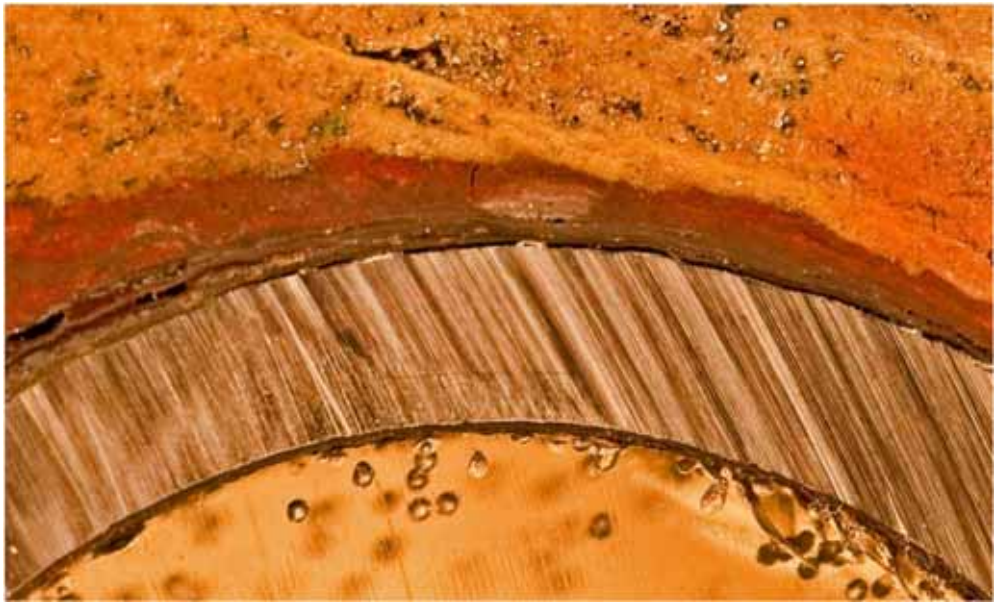


Corrosion probes in the superheater position



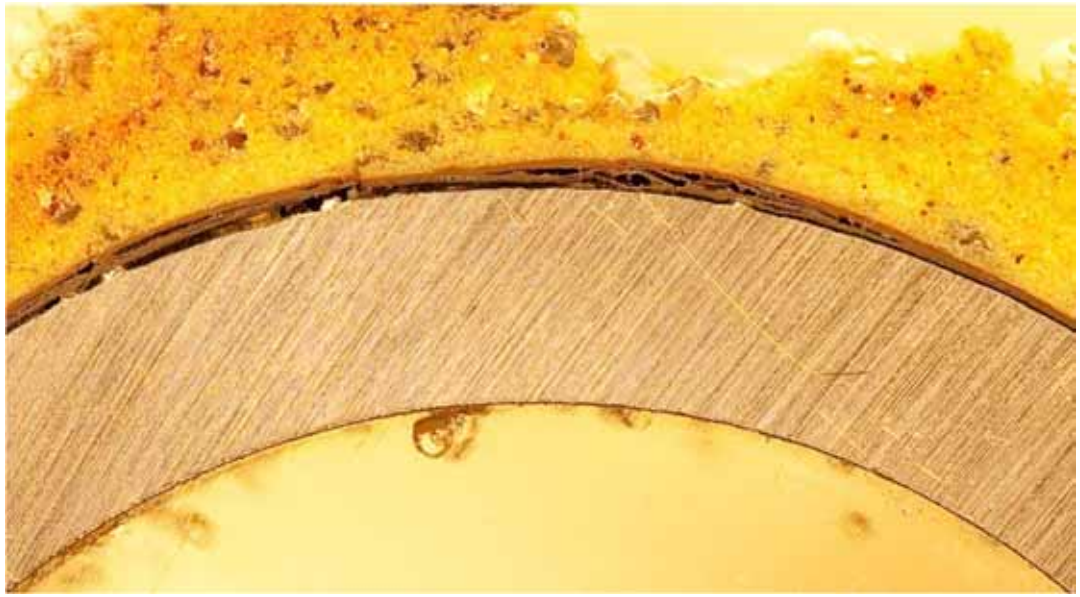
(wt%)	Cr	Ni	Mn	Si	Mo	Fe	n_{Cr}/n_{Fe}	Add. elements
16Mo3	-	-	0.6	-	0.3	99.1	0	-
Sanicro 28	27.0	31.0	2.0	0.6	3.5	34.5	0.8	Cu: 1
Inconel 625	22.0	58.0	0.5	0.5	9.0	5.0	4.4	-

16Mo3 - Photograph - 525 °C



Reference

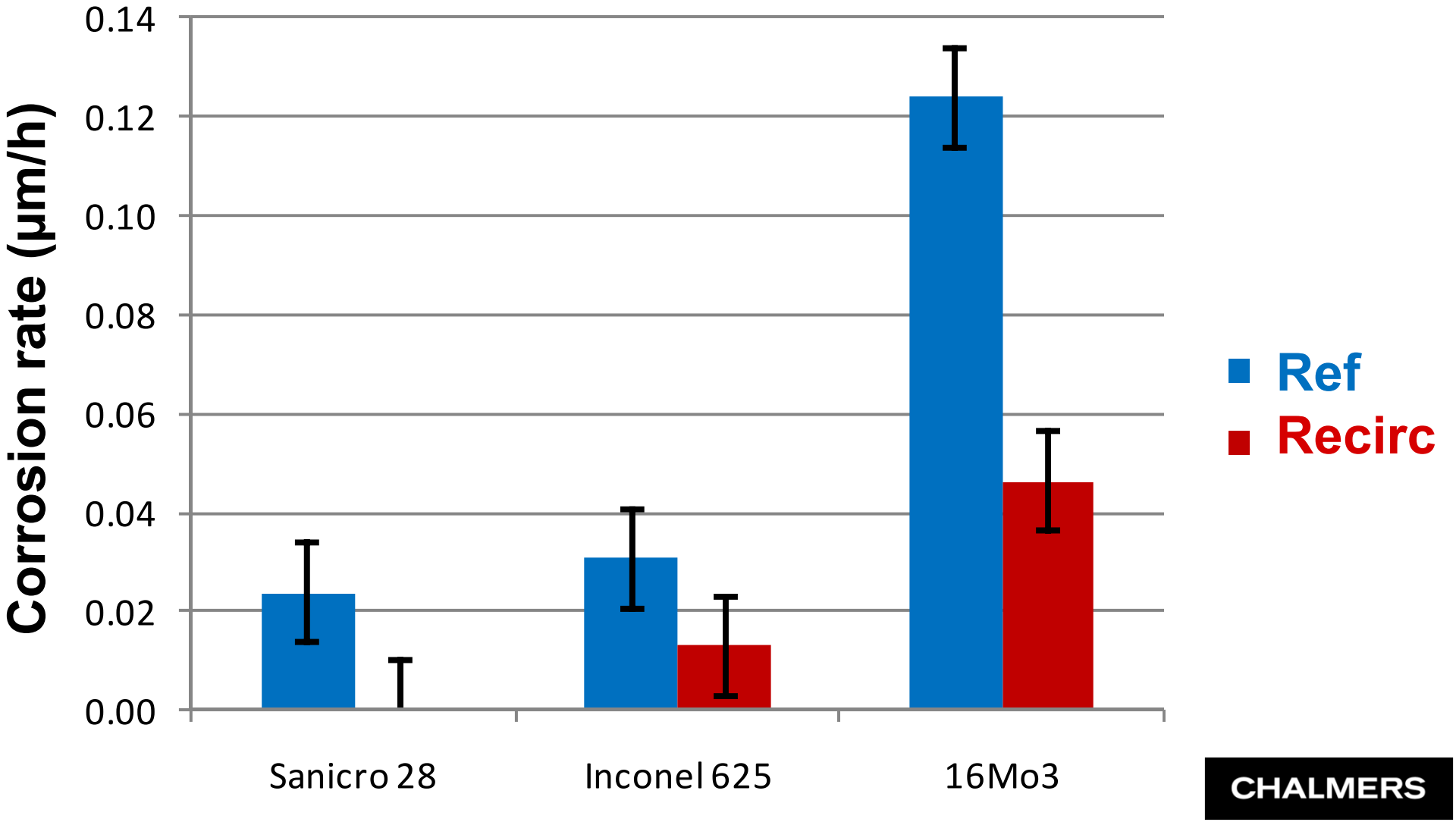
16Mo3



Sulphur Recirculation

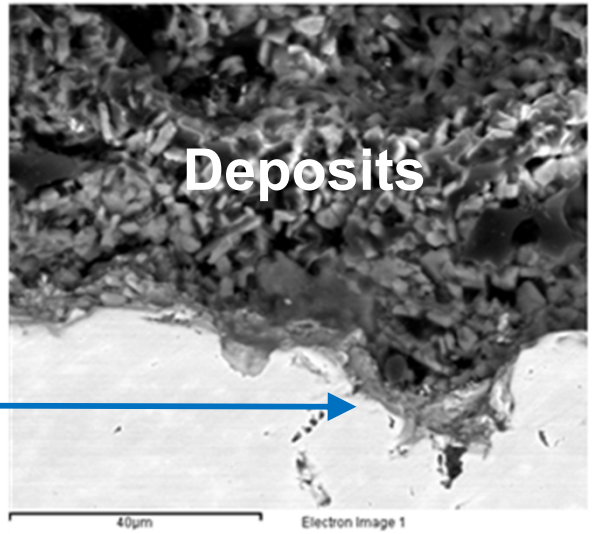
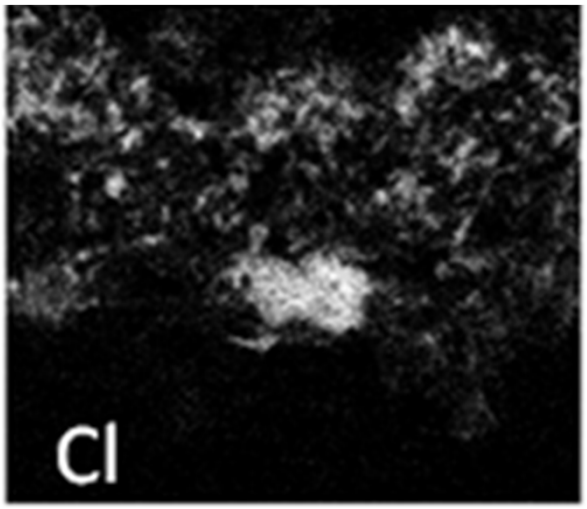
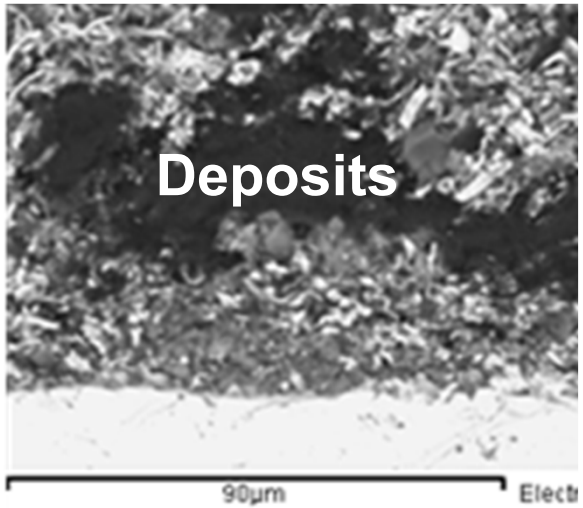
16Mo3

Corrosion rate at material temp 450°C (1000 h)



Inconel 625 - SEM/EDX images - 450°C

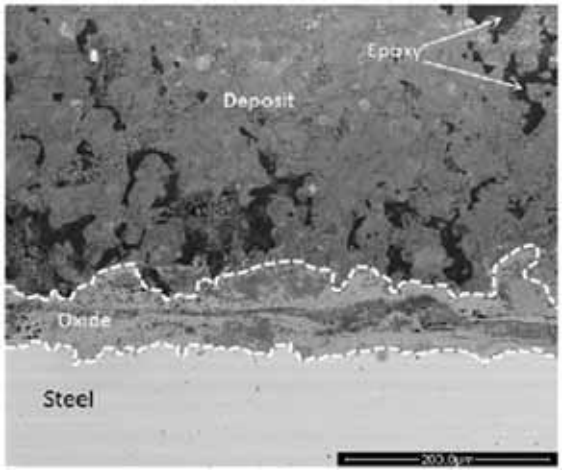
GÖTAVERKEN MILJÖ

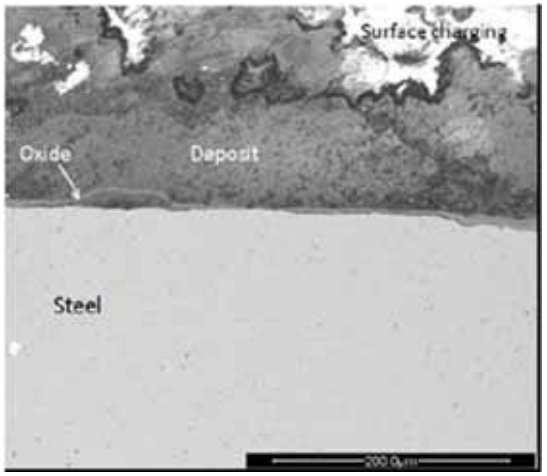
	SEM	EDX map for chlorine
1000 h Reference Corrosion attack →		
1000 h Recirculation Unaffected surface →		

Sanicro 28 - 1000h

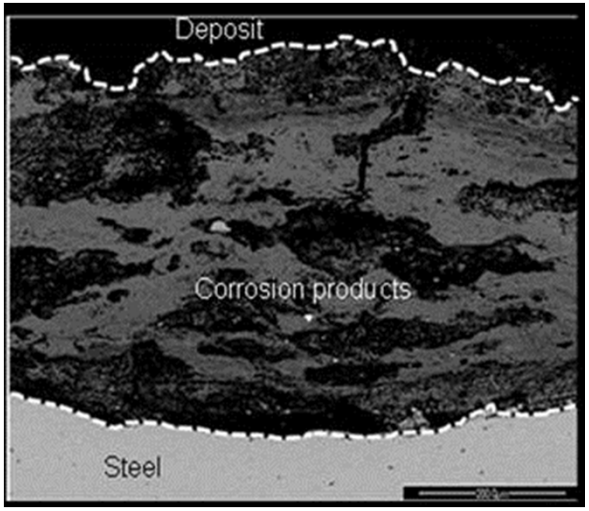
GÖTAVERKEN MILJÖ

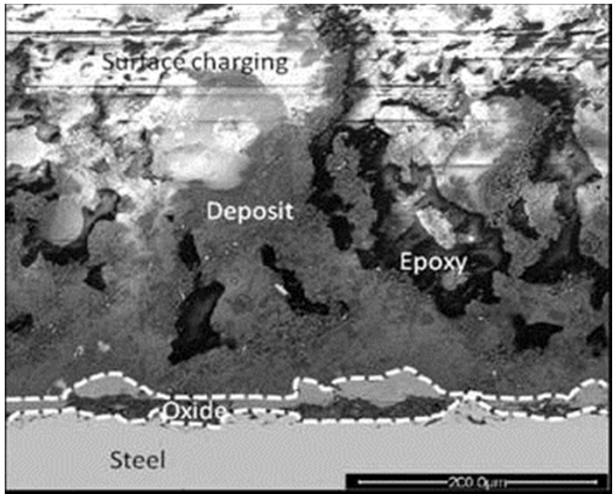
450°C





525°C

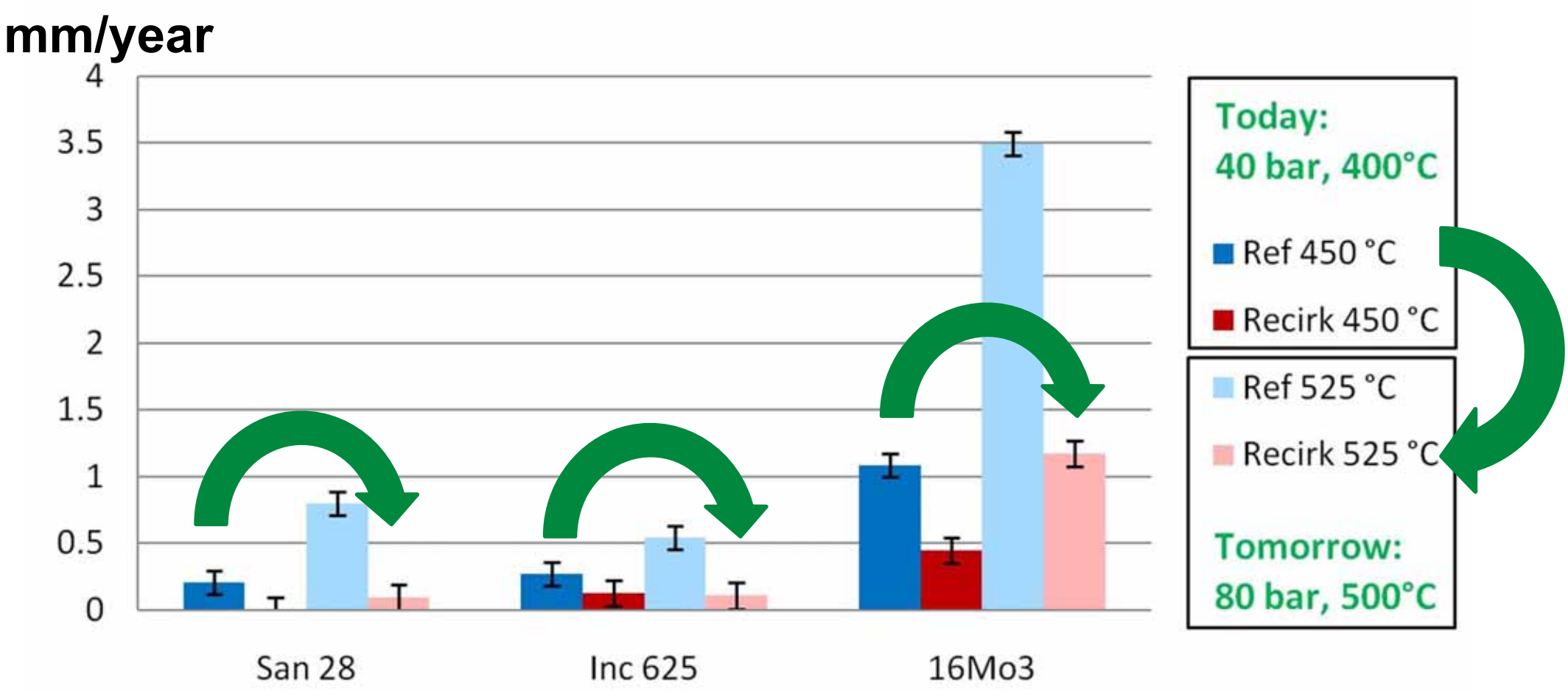




1000 h Reference

1000 h Recirculation

1000 h Corrosion rate measurements

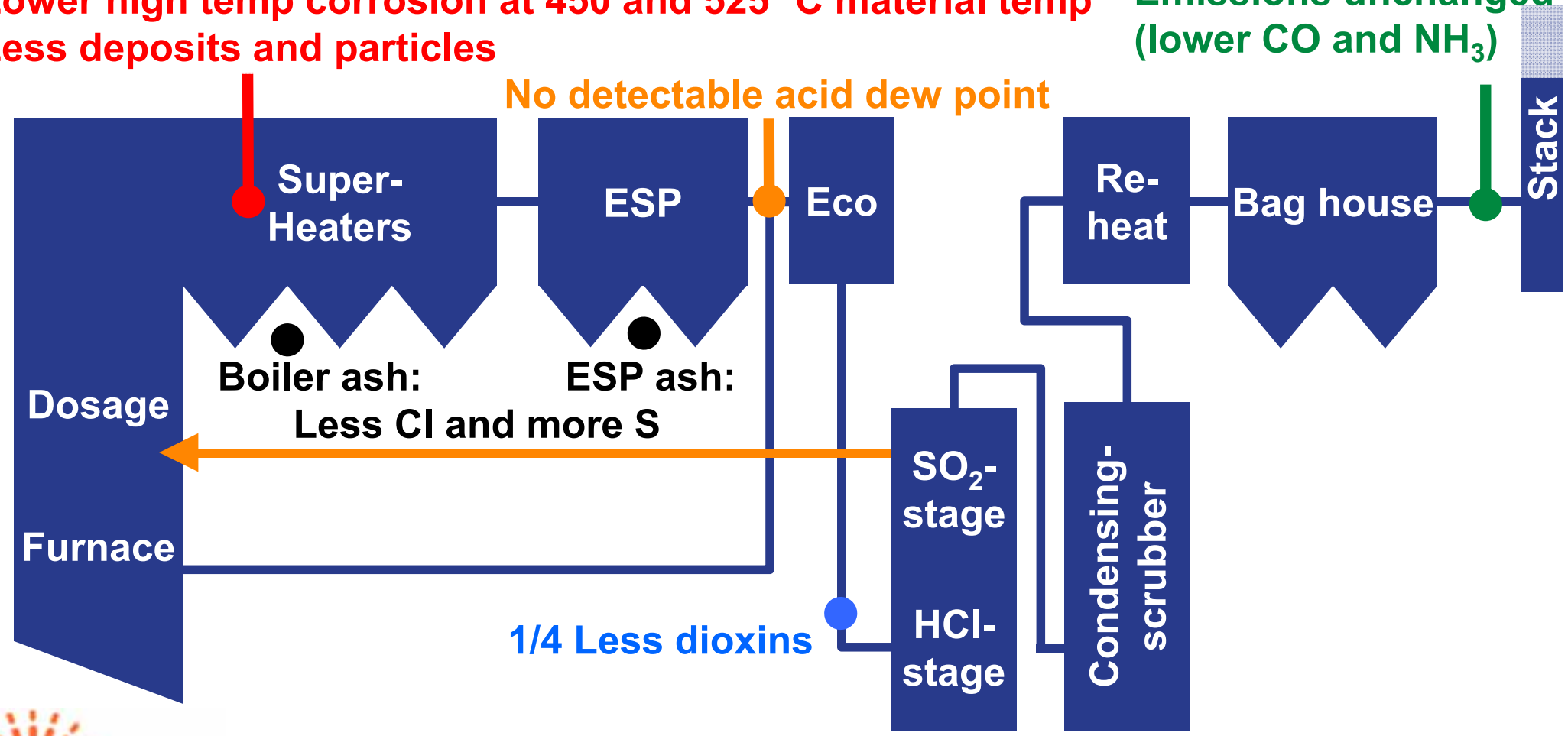


Sulphur recirculation enables higher steam data

Summary

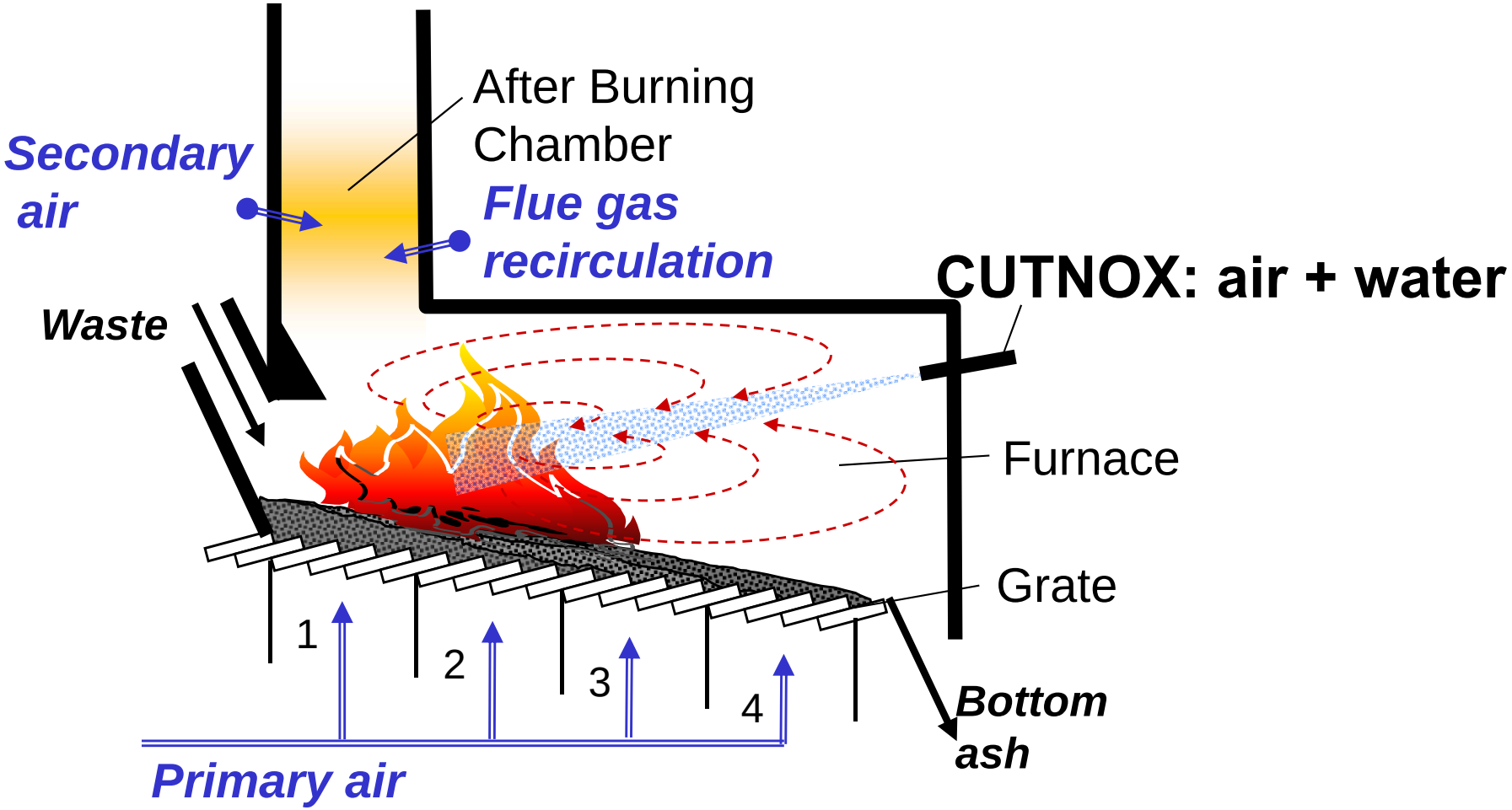
Lower high temp corrosion at 450 and 525 ºC material temp
Less deposits and particles

Emissions unchanged
(lower CO and NH_3)



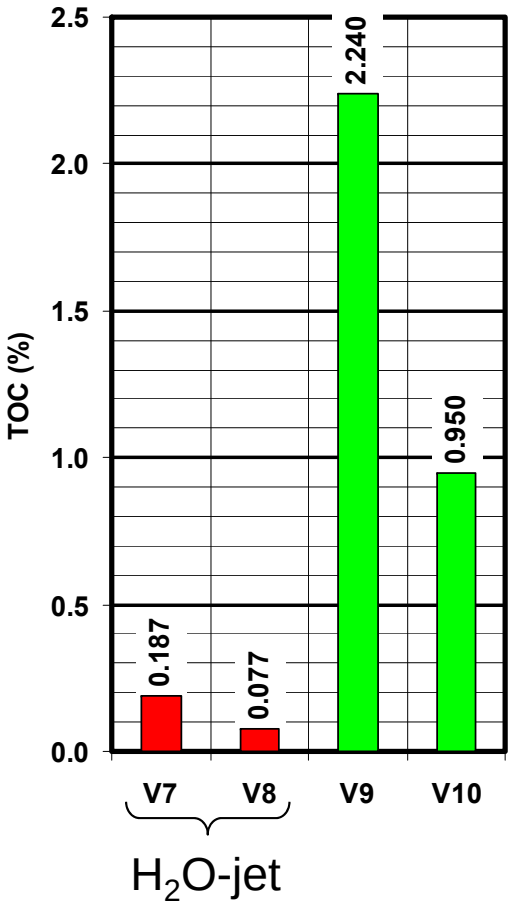
Renova
GARANTERAD ÅTERVINNING

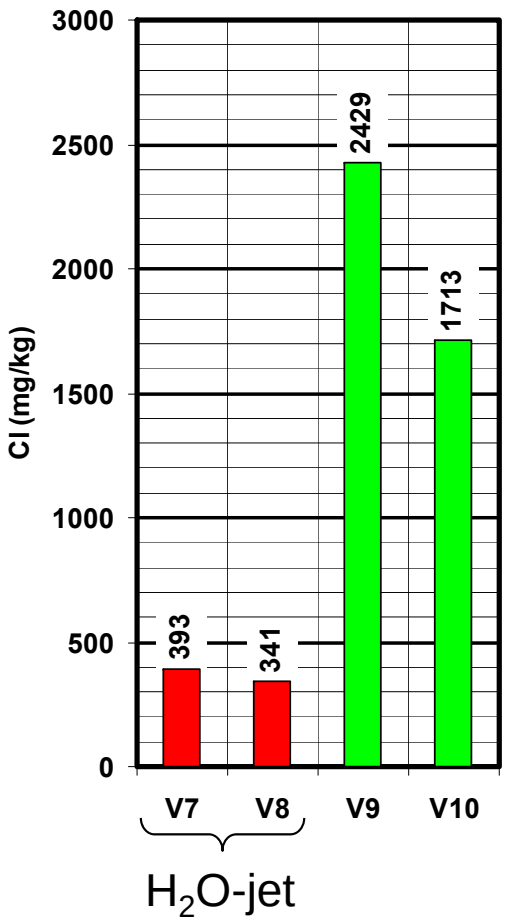
NO_x primary measure: CUTNOX

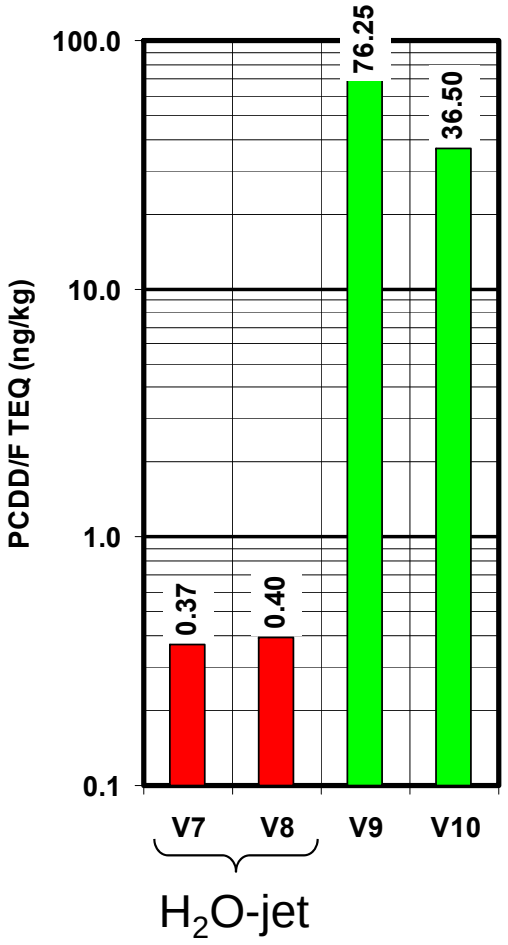


Lower temp. and increased mixing at λ<1
promote formation of N_2 and reduce formation of NO

Test at TAMARA: Pilot grate fired furnace (0,5 MW_{th})





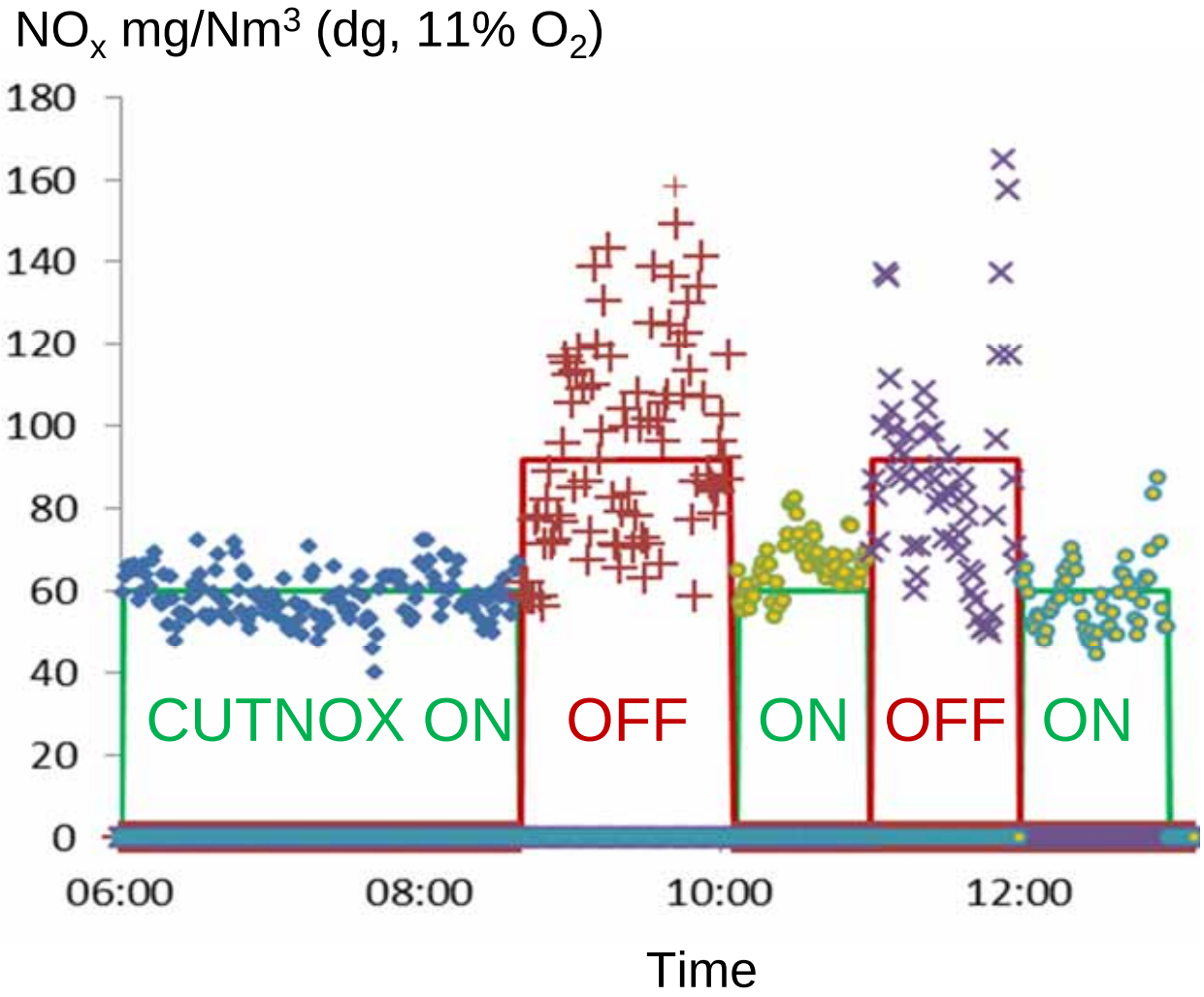


Less TOC, Cl and PCDD/Fs in the bottom ash

NO_x: First commercial CUTNOX at Renova (SE)

GÖTAVERKEN MILJÖ

Preliminary results from CUTNOX ON/OFF tests: Optimisation in progress

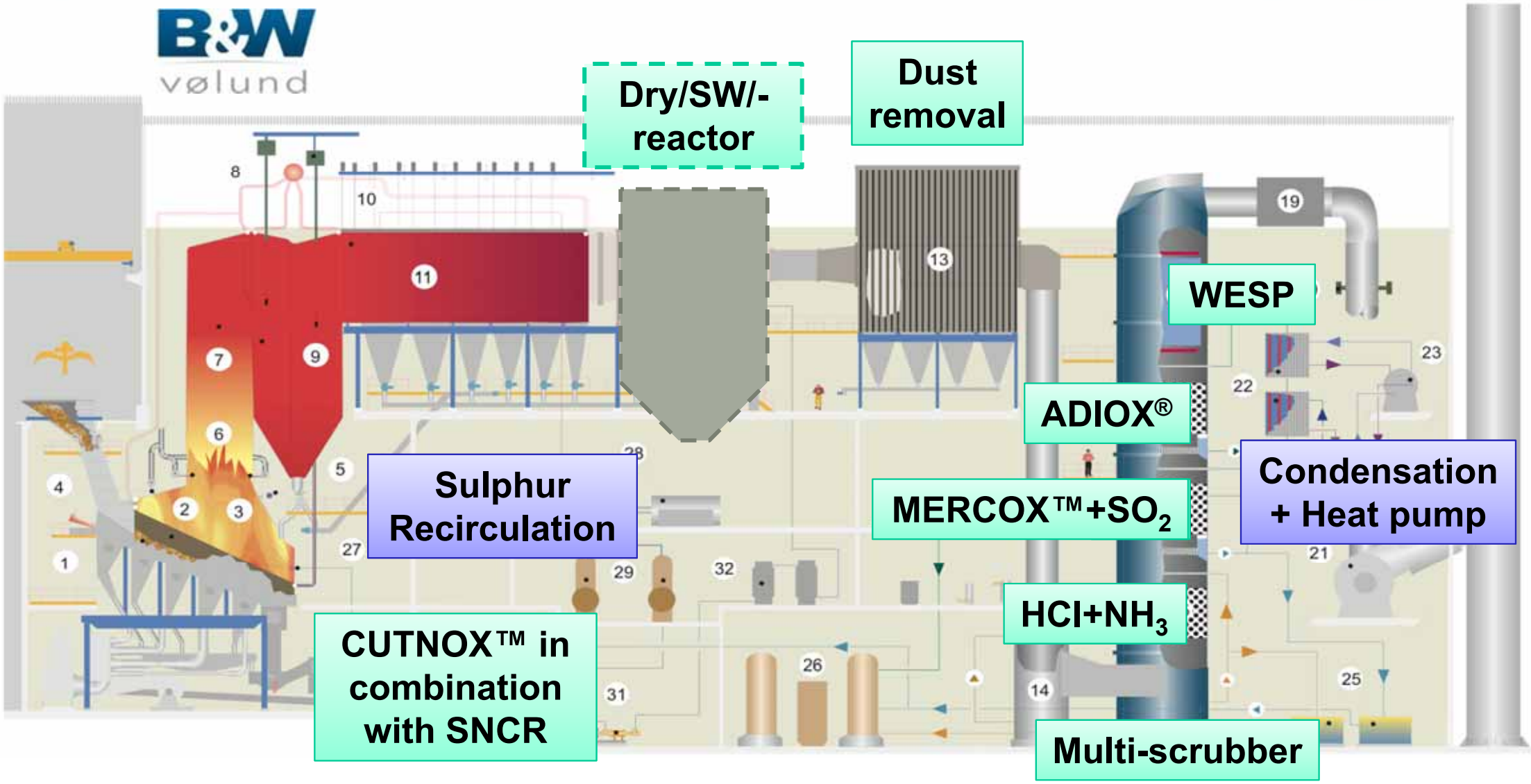


OFF = 92 (mg/Nm³ d.g.)

ON = 60 (mg/Nm³ d.g.)

Corresponding to 34% NO_x reduction

NextBAT® flue gas treatment

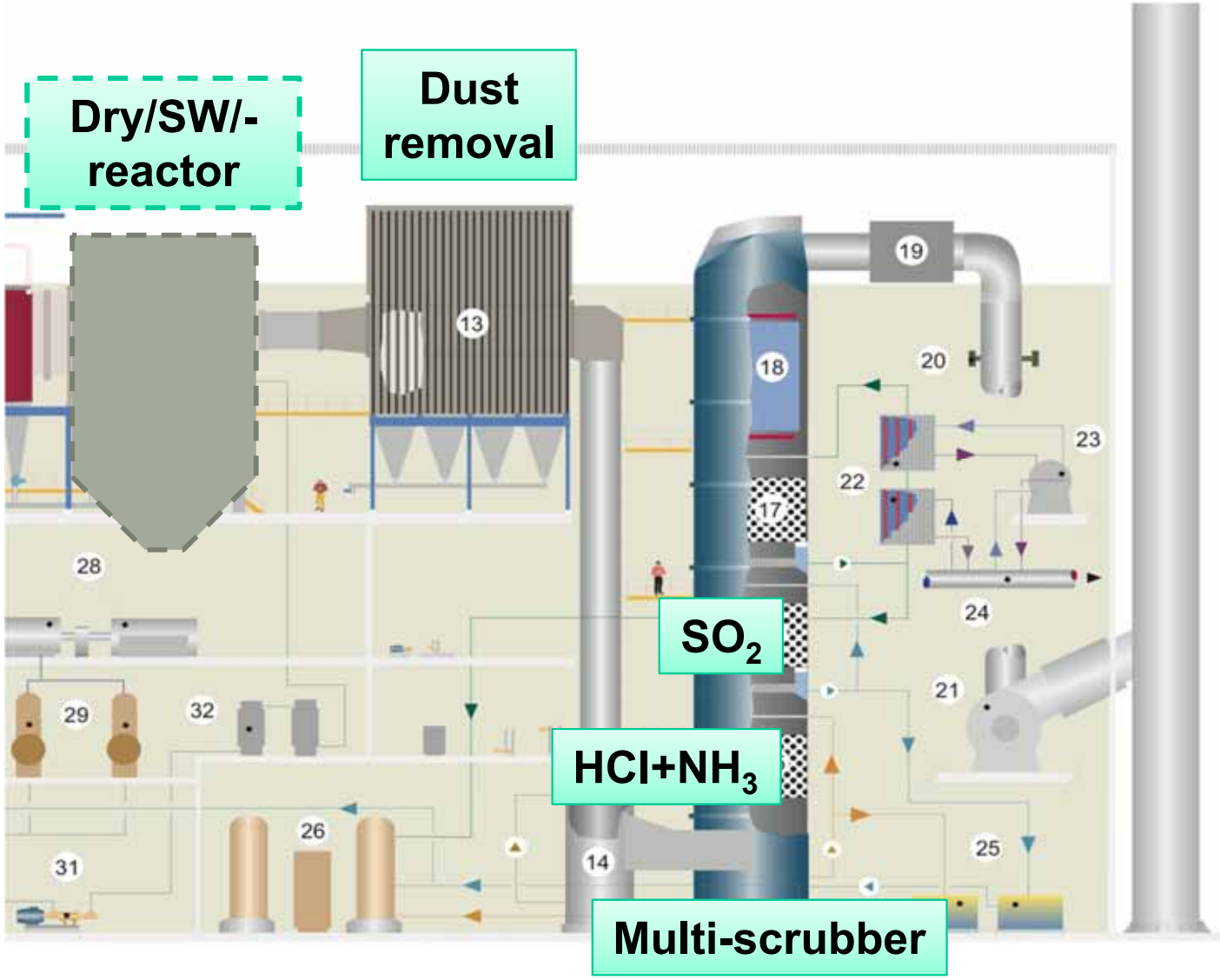


$HCl+SO_2$ removal

Wet scrubbers yield extremely low emission values: Insensitive to HCl/SO_2 ratio

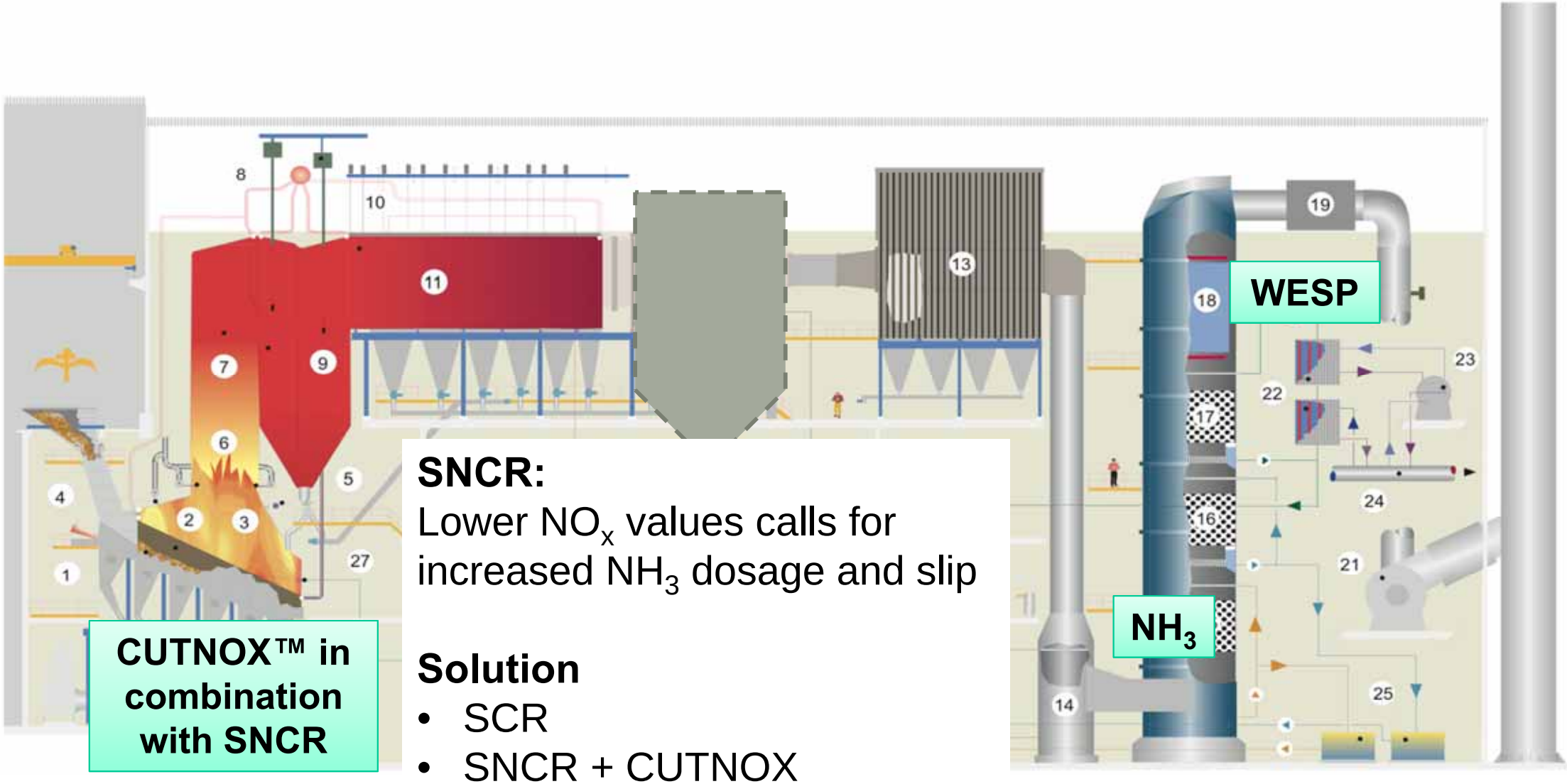
Waste water free:
Dry or semi-wet
+ slip scrubber

$Cl^- + SO_4^{2-}$
to water recipient:
Wet scrubber



$NO_x + NH_3$

GÖTAVERKEN MILJÖ



SNCR:
Lower NO_x values calls for increased NH_3 dosage and slip

Solution
- SCR
- SNCR + CUTNOX

CUTNOX™ in combination with SNCR

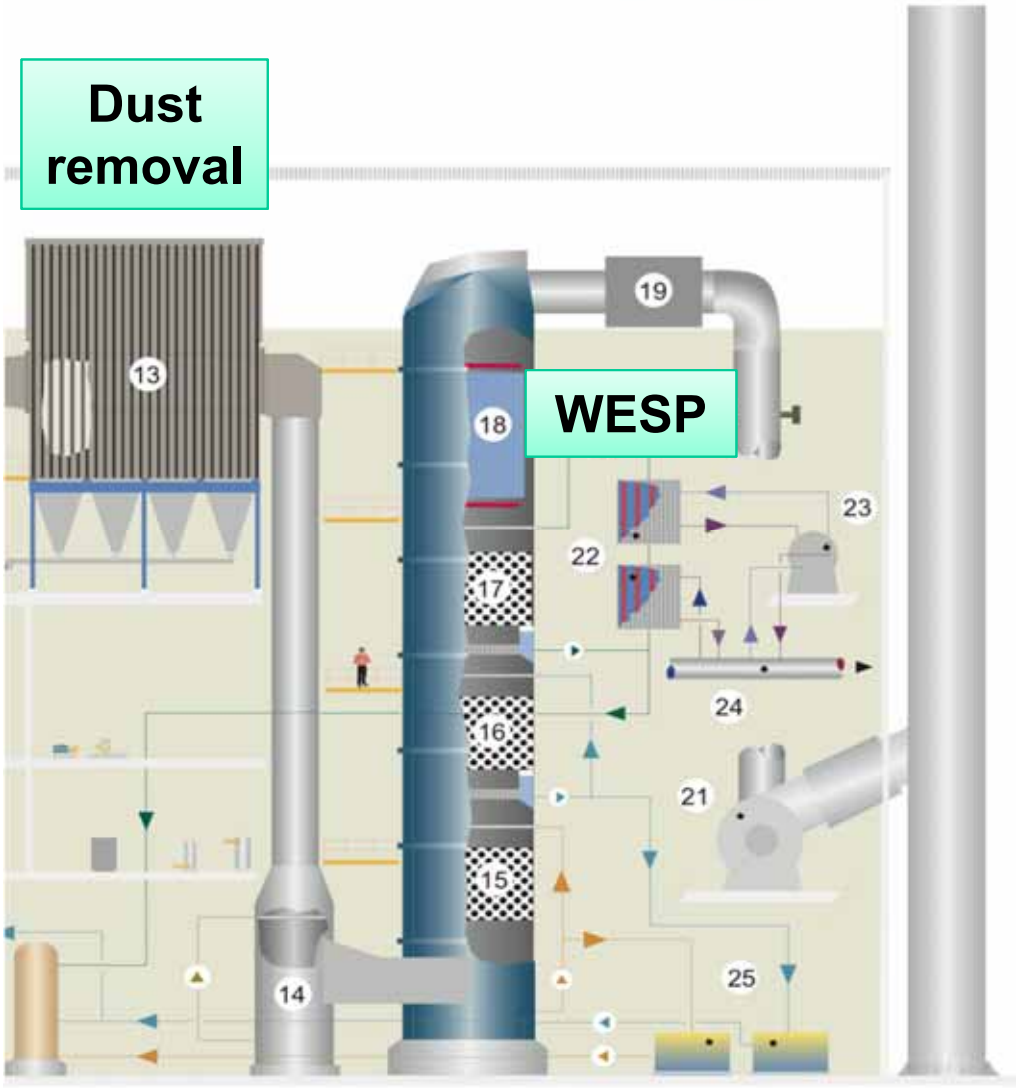
Dust / fine particles

Problem
PM2.5 in ambient air causes premature death of 350 000 EU citizens per year.

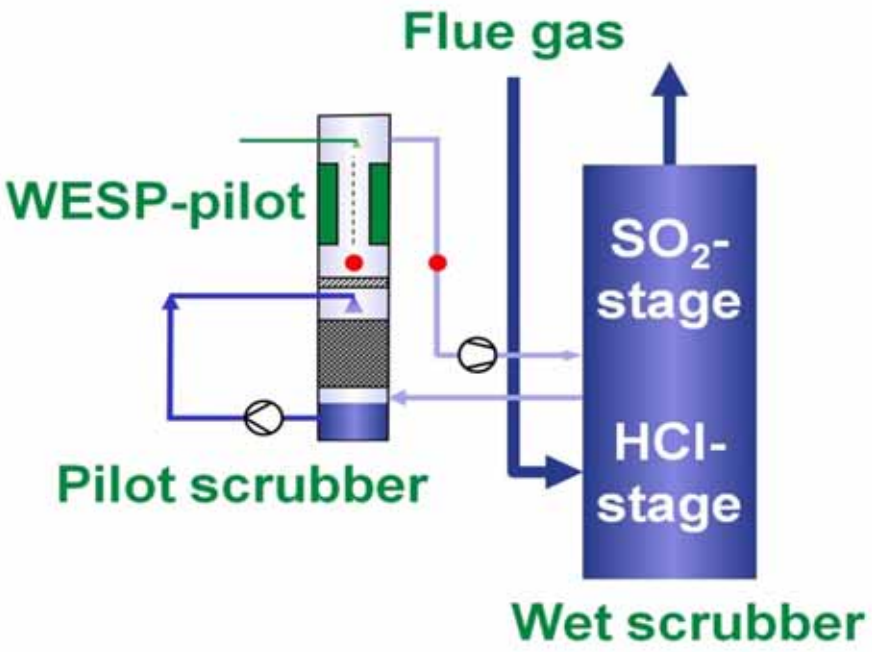
In many urban environments, the ambient air levels of PM2.5 are higher than stipulated by EU directives.

Solution
Dust concentrations < 1 mg/Nm^3 (10% of emission limit) can be reached by:

- Bag house filter
- ESP + scrubber integrated WESP



Dust: Scrubber Integrated WESP



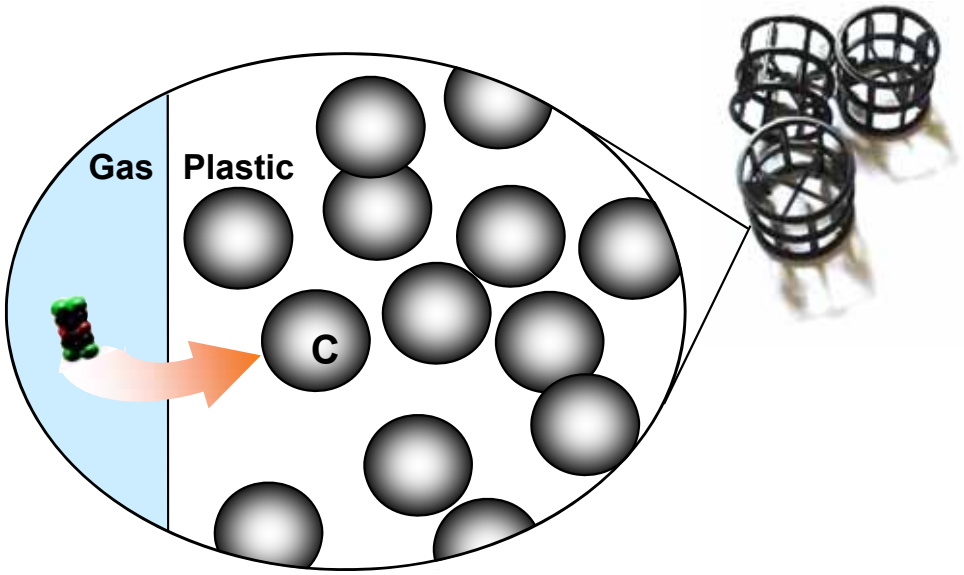
- New scrubber integrated WESP (Wet Electro Static Precipitator) developed by Götaverken Miljö and AWS Corp (IT).
- Fabricated in corrosion resistant conductive FRP
- Cooled condensing collector

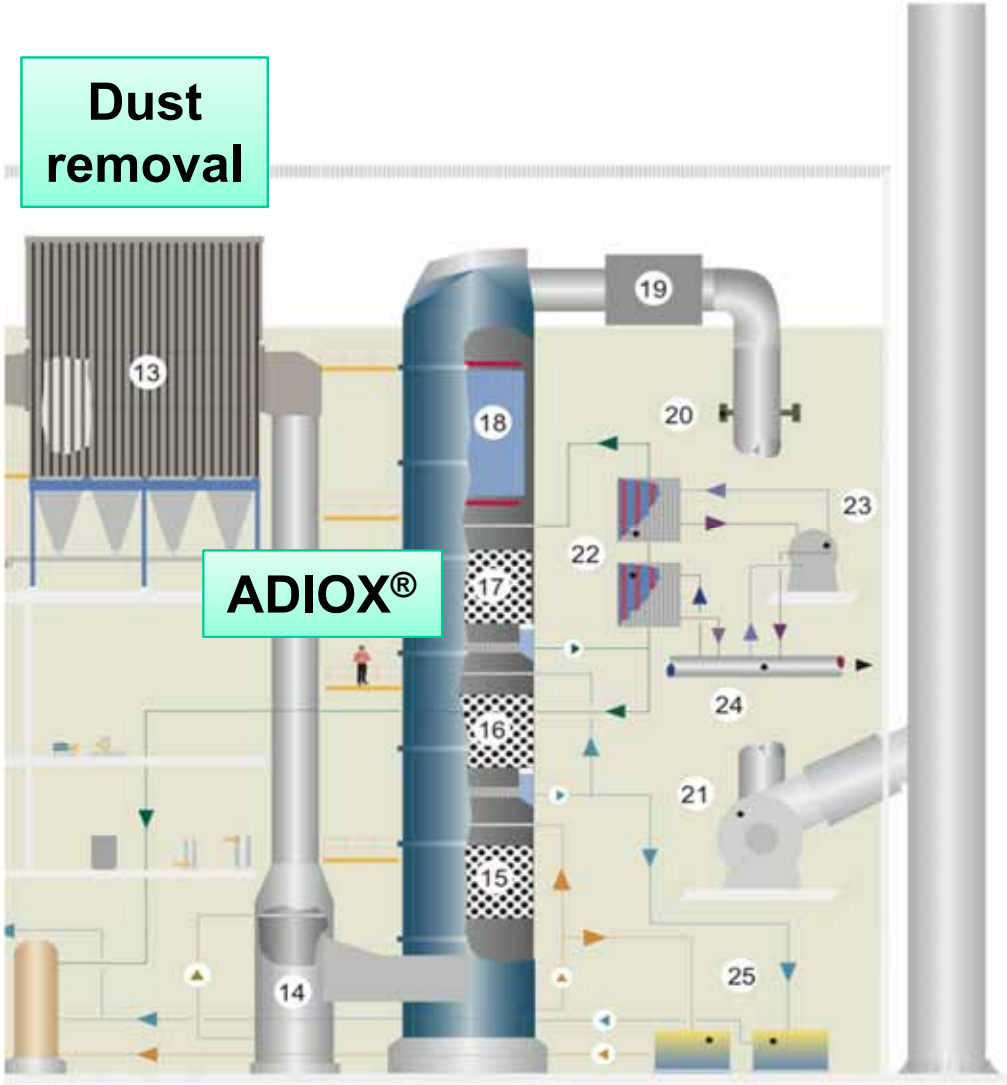
- **All clean gas dust measurements <0,3 mg/Nm³ dg.**
- **Mean removal efficiency >99%**

PCDD/F removal

- **Bag house filter + carbon injection**
  + ADIOX for Memory Effect minimisation

- **ESP + ADIOX**
  ADIOX can be incinerated after use –
  thereby taking dioxins out of the eco-cycle





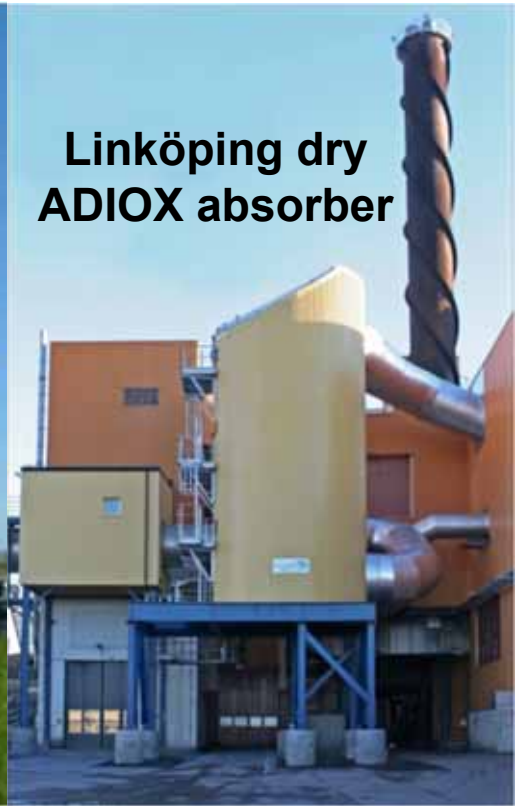
PCDD/F removal: ADIOX®

- Dioxin absorption in carbon filled polymer
- ADIOX material in packings and demisters
- If required a separate ADIOX absorber unit

- Always on-line to absorb dioxin
- Efficient also during plant start-up

Scrubber interior

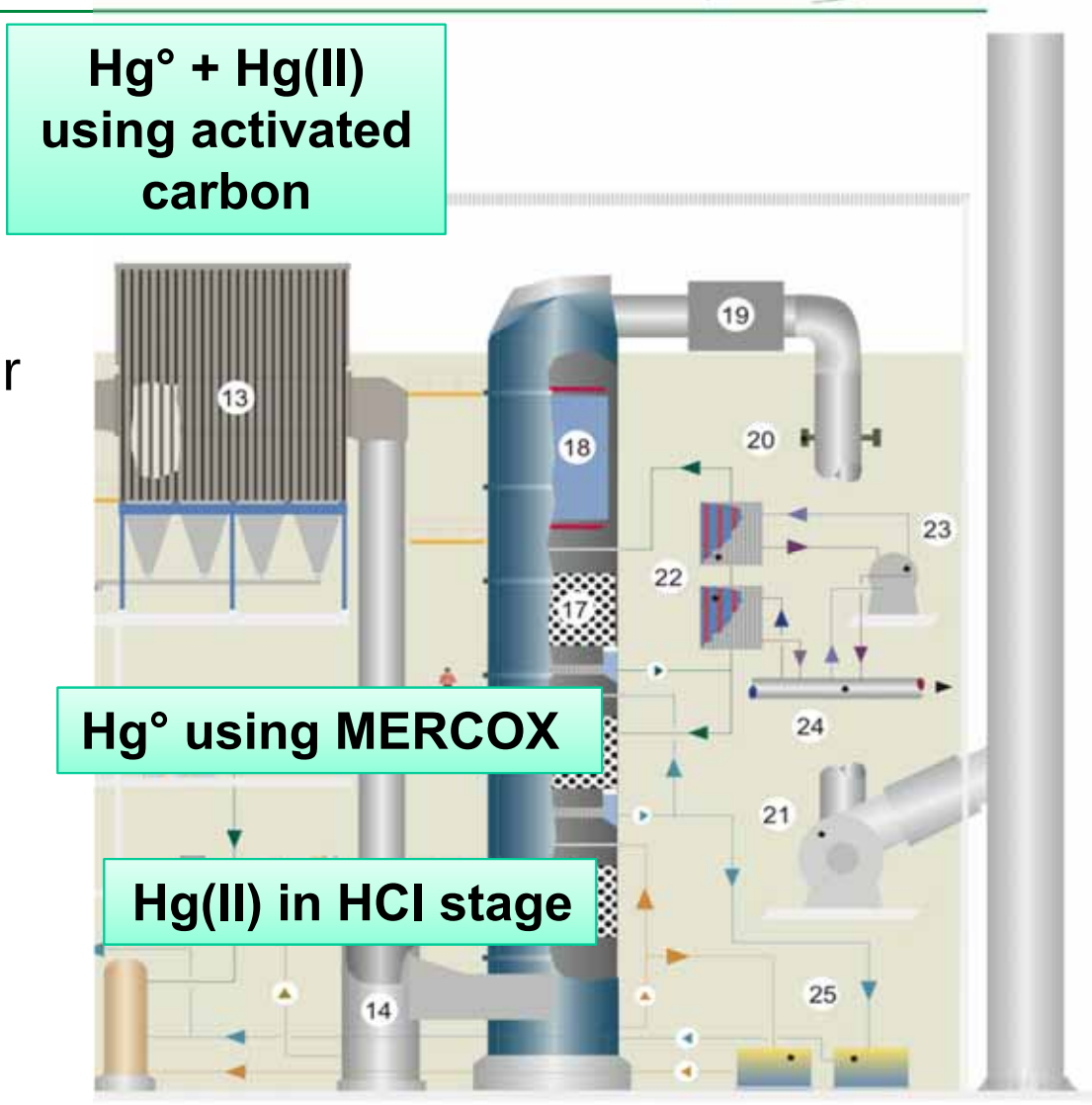
ESP+ADIOX



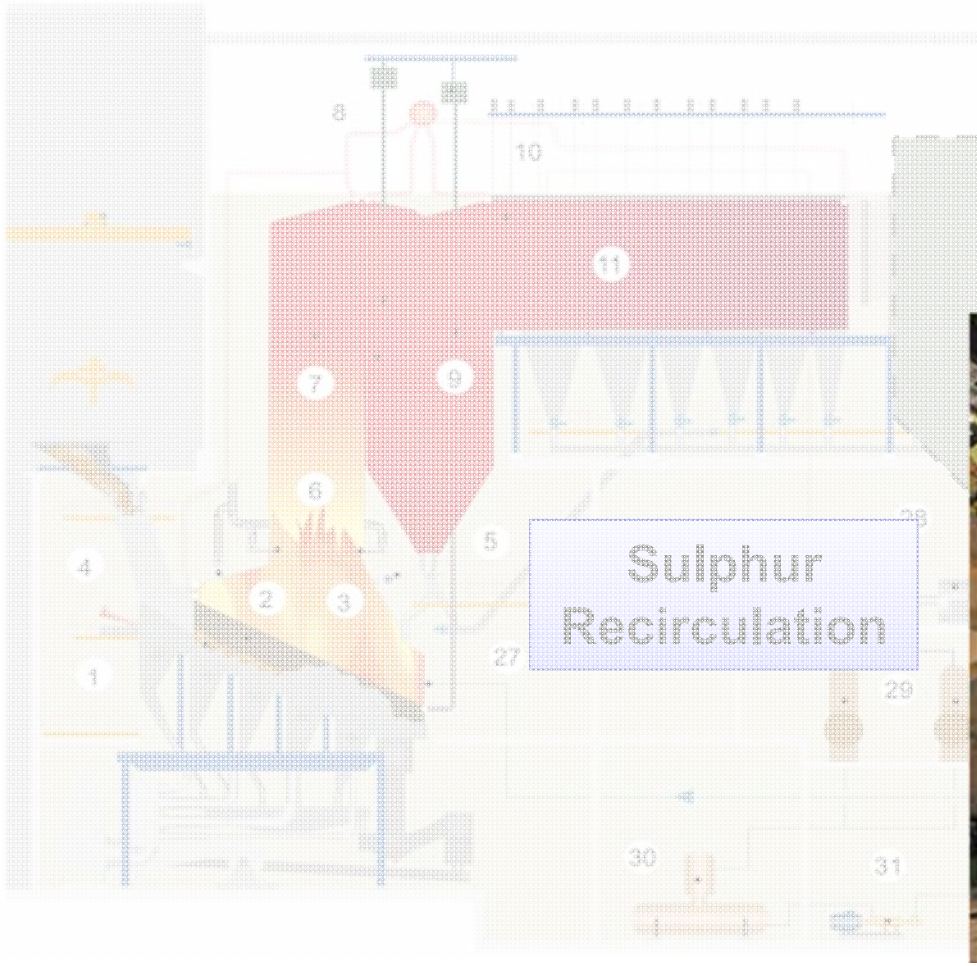
Linköping dry ADIOX absorber

Hg

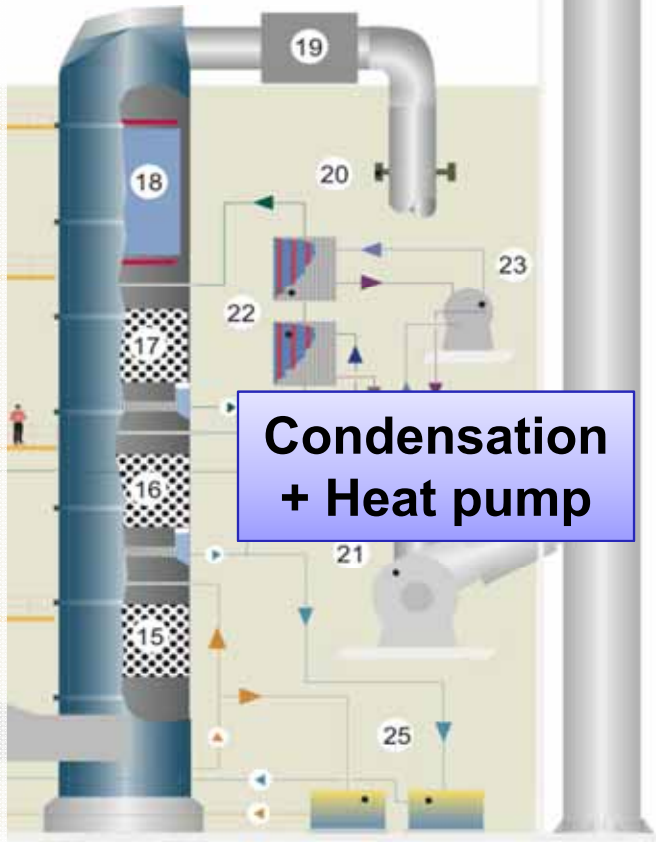
- **Bag house filter + carbon injection** is normally sufficient for Hg removal
- **MERCOX** in case of very high Hg loads or very low emission values



Energy recovery

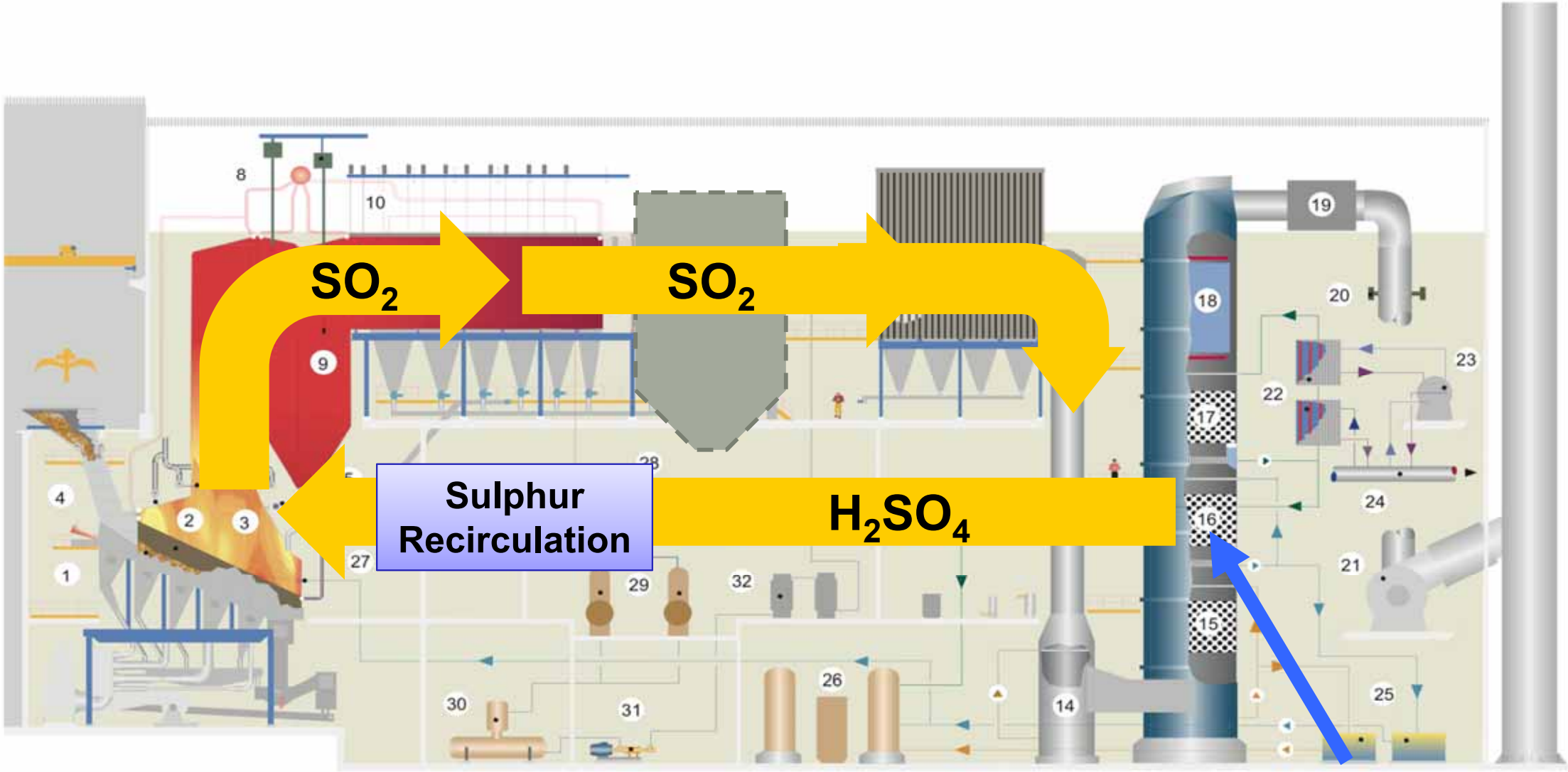


Vestforbraending absorption heat pump



- Increased energy recovery by some 20-25 % by condensation with heat pumps

Energy efficiency: Sulphur Recirculation

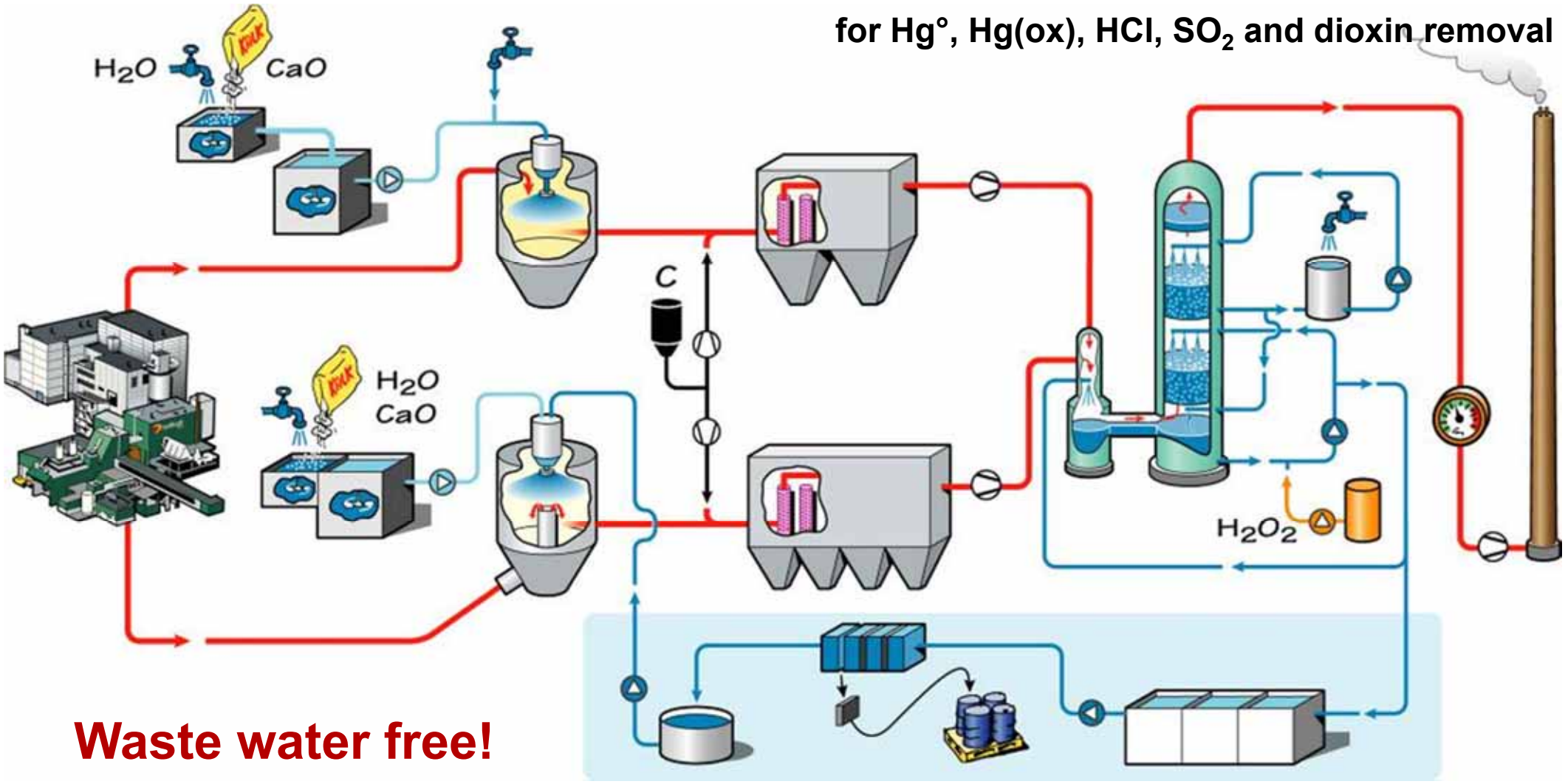


Hg: Sakab Hazardous waste incinerator, Sweden

GÖTAVERKEN MILJÖ

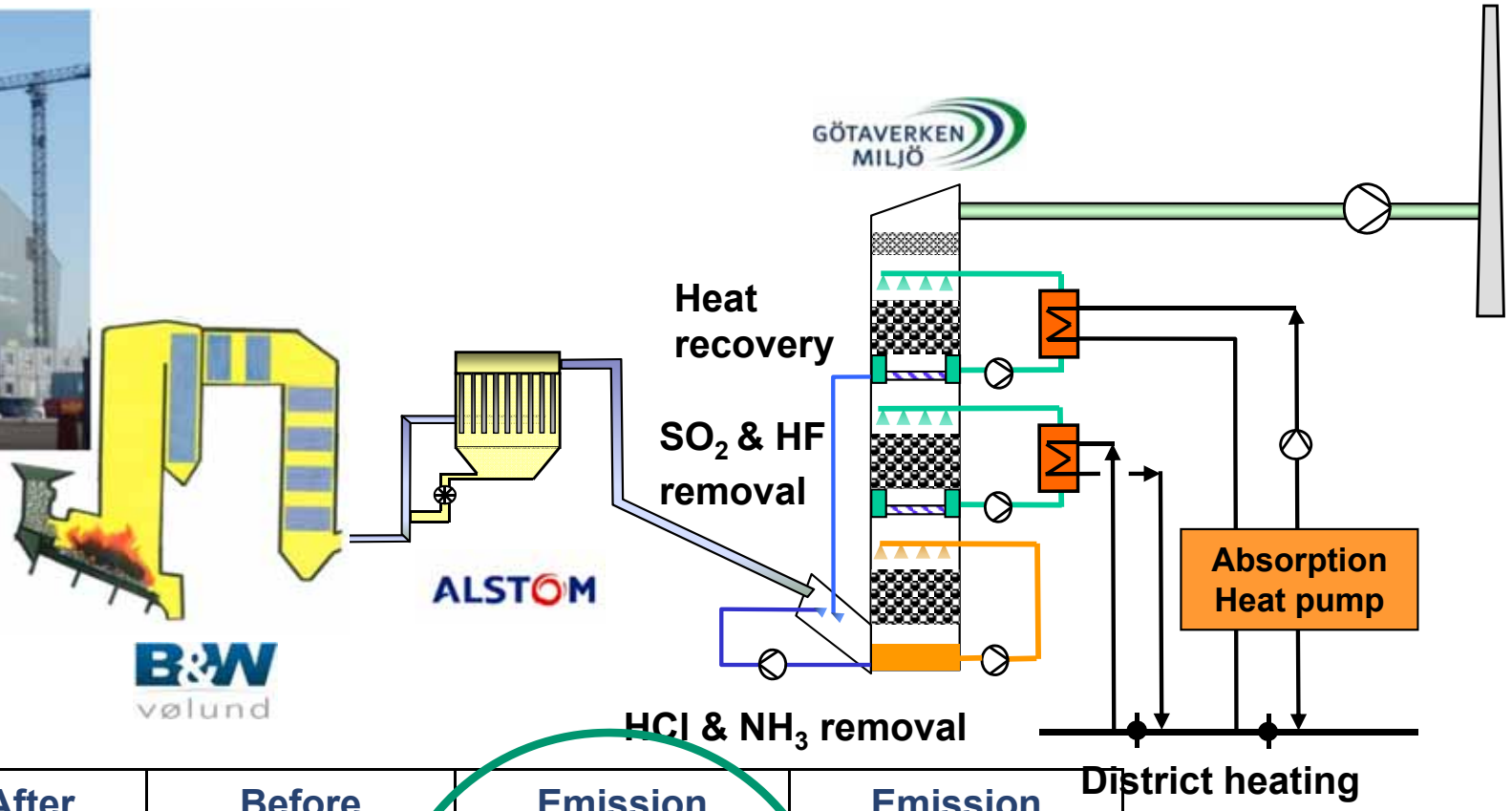
Multifunctional MercOx- and ADIOX scrubber

for Hg°, Hg(ox), HCl, SO_2 and dioxin removal



Waste water free!

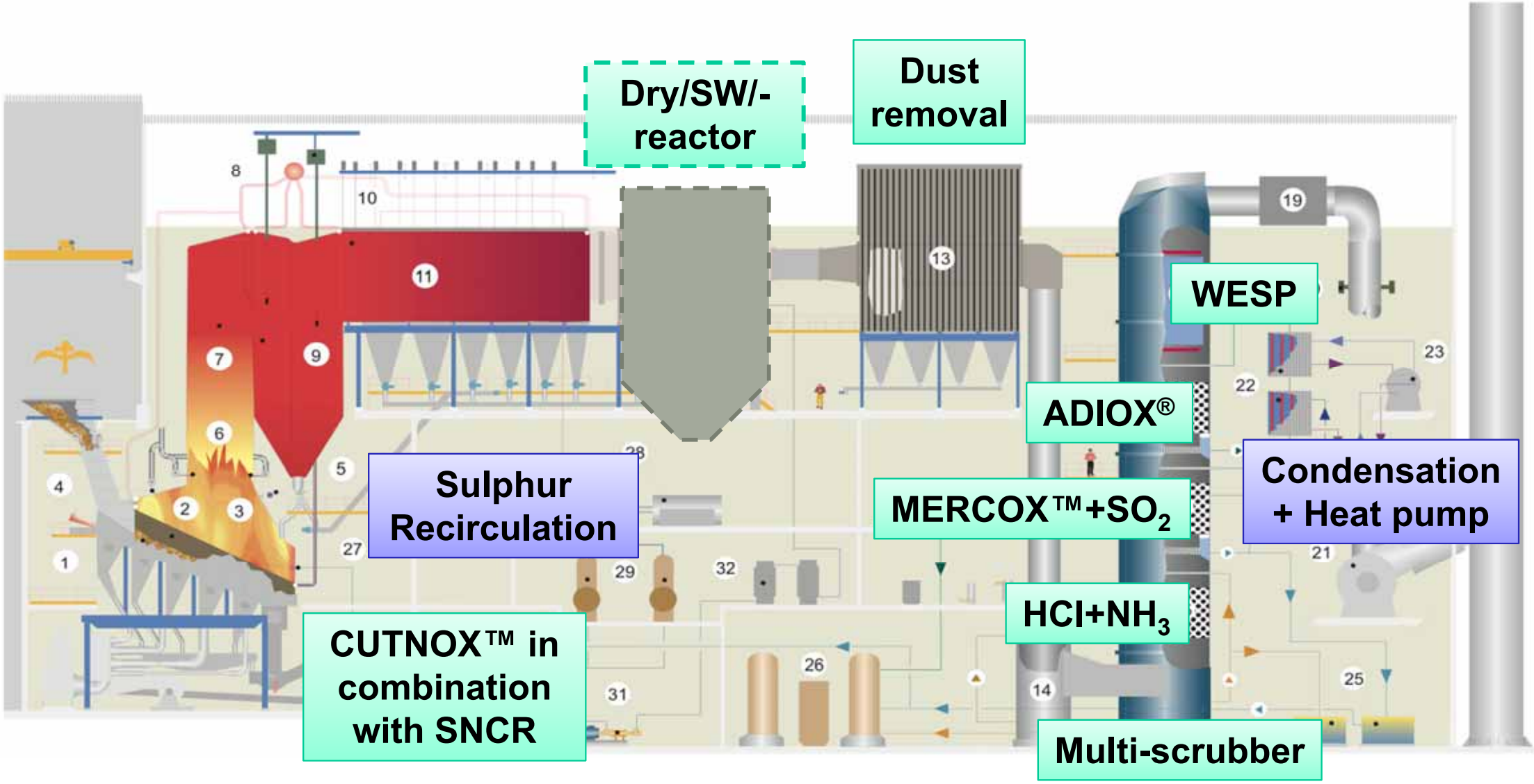
Filborna, Helsingborg (SE)



Emissions:

	Units	After boiler	Before scrubber	Emission guarantee	Emission expected
HCl	mg/Nm³	2000	45	5	~ 1
SO_2	mg/Nm³	1000	50	25	~ 1
HF	mg/Nm³	30	1	0.5	~ 0.1
PCDD/Fs	ng/Nm³	10	0,05	0,05	~ 0.02

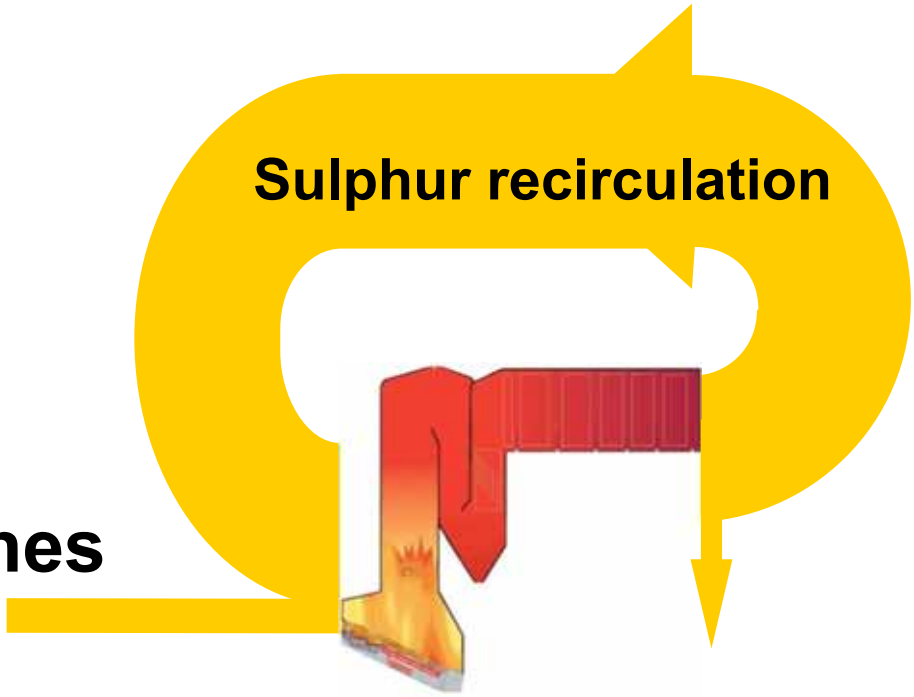
Conclusions



Conclusions

- Reduced NO_x concentration / NH_3 consumption
- Less TOC, Cl and PCDD/Fs in the bottom ash
- Smaller variations in temperature and steam flow

Conclusions



- **Potential for sulphate waste water free operation**
- **Less dioxins, deposits and ashes**
- **More electricity production or less corrosion**

sven.andersson@gmab.se

GÖTAVERKEN MILJÖ