

CFB 9 Conference, Hamburg-Harburg 2008

# **THE ROLE OF CFB IN CO- COMBUSTION**

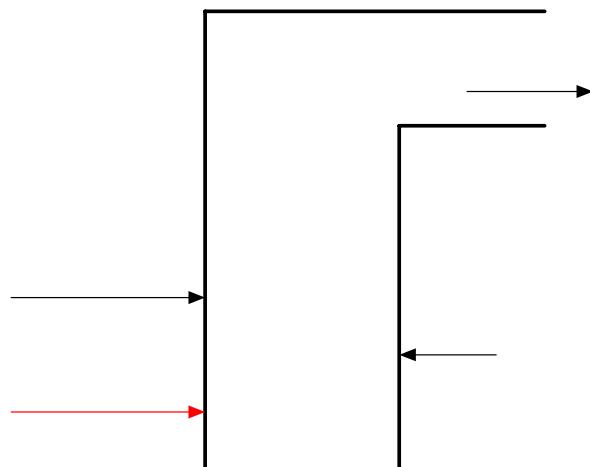
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# CONTENT

- A general survey of co-combustion
- Judgement on advantages and disadvantages of co-combustion in general, including CFB
- The role of CFB

# DEFINITION

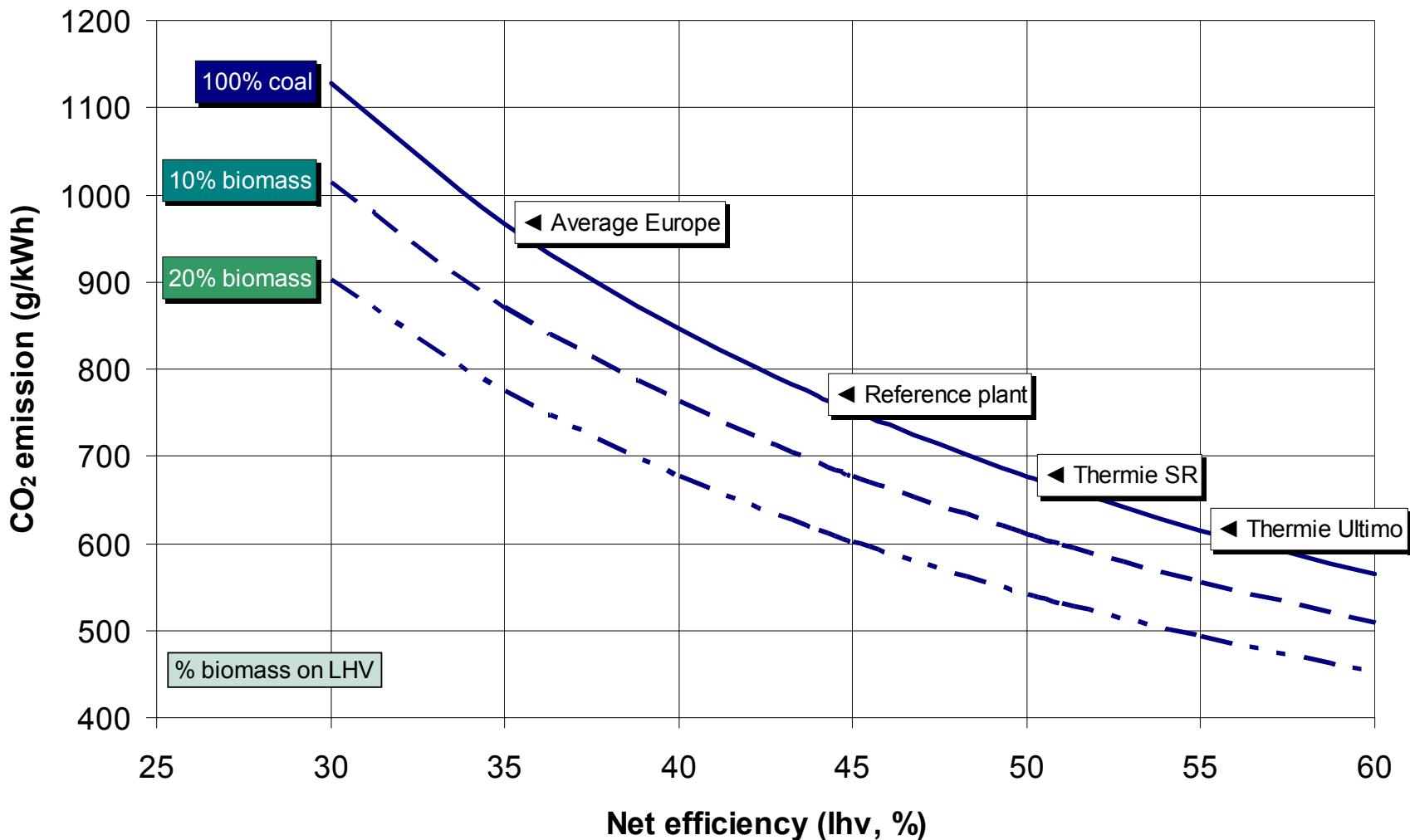
Co-combustion or co-firing is to burn or to convert two or more fuels together in one boiler system



# PURPOSE OF CO-COMBUSTION

- Spontaneous—many applications in FBC depending on available fuels and prices
- Substitution of fossil fuels ---utilization of biomass and waste for CO<sub>2</sub> reduction
- Waste reduction with energy utilization

# REDUCTION OF CO<sub>2</sub> EMISSION BY INCREASED EFFICIENCY AND CO-COMBUSTION

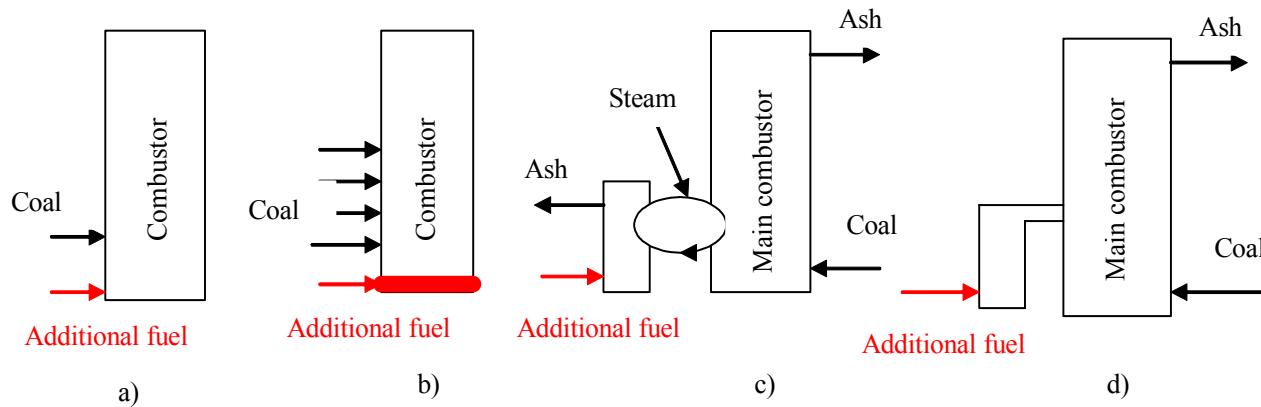


## FOUR SITUATIONS:

1. A small fraction of fuel (biomass or waste) is burned together with the base fuel (coal) in a utility boiler
2. A small amount of high-value fuel (coal) is added to support combustion of a low-value fuel (waste).
3. Any fuel proportions are mixed in a furnace for industrial or district heating
4. Gas from the additional fuel is produced in a gas generator to partially replace gas, pulverized coal in one or several burners in a boiler

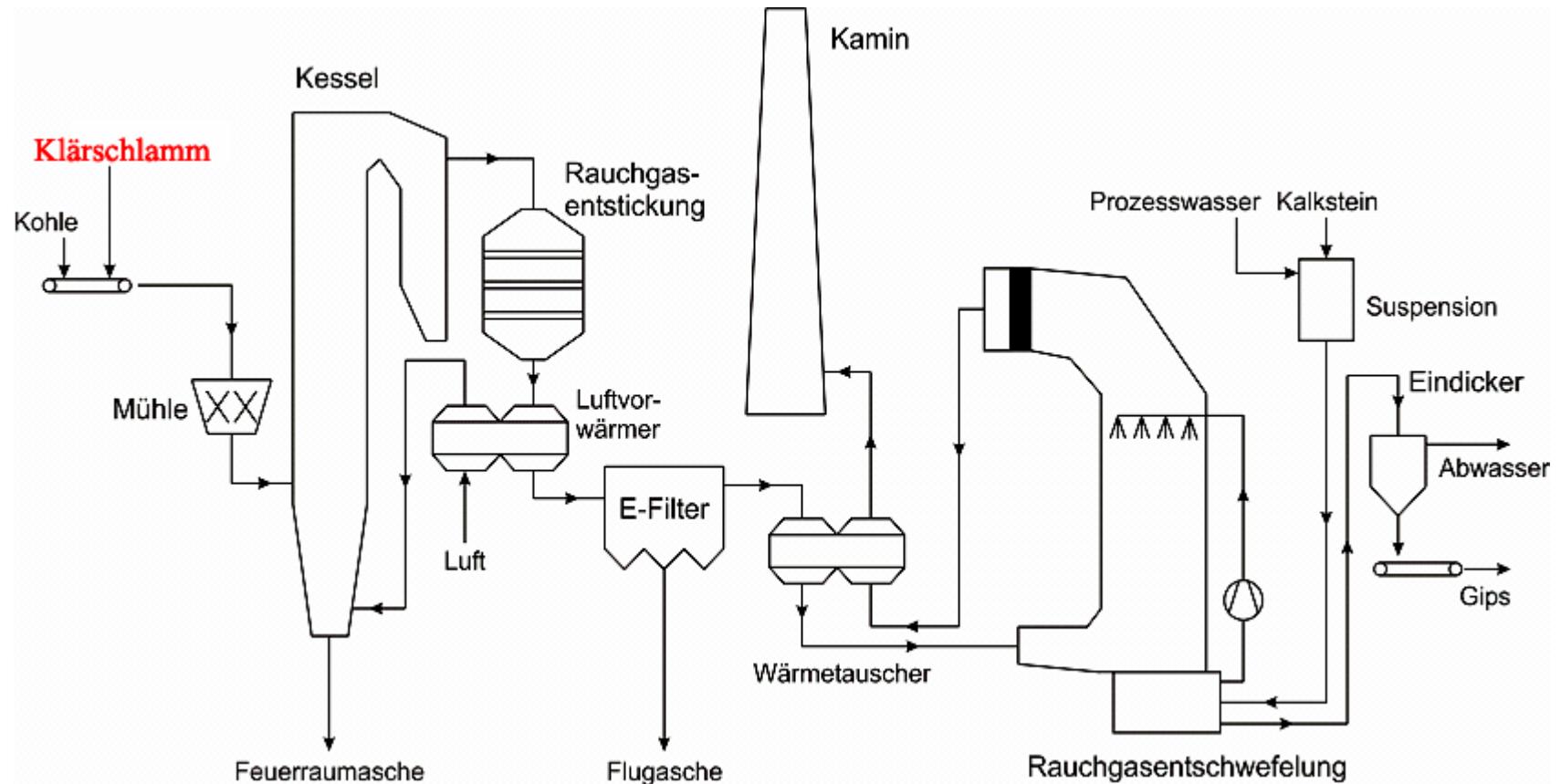
# FIVE TECHNIQUES OF CO-COMBUSTION:

- a) Together with the base fuel (PC and FBC)
- b) Additional bed to a PC furnace
- c) Additional combustor connected on the steam side
- d) Additional combustor connected on the gas side
- e) Additional fuel for reburning or afterburning

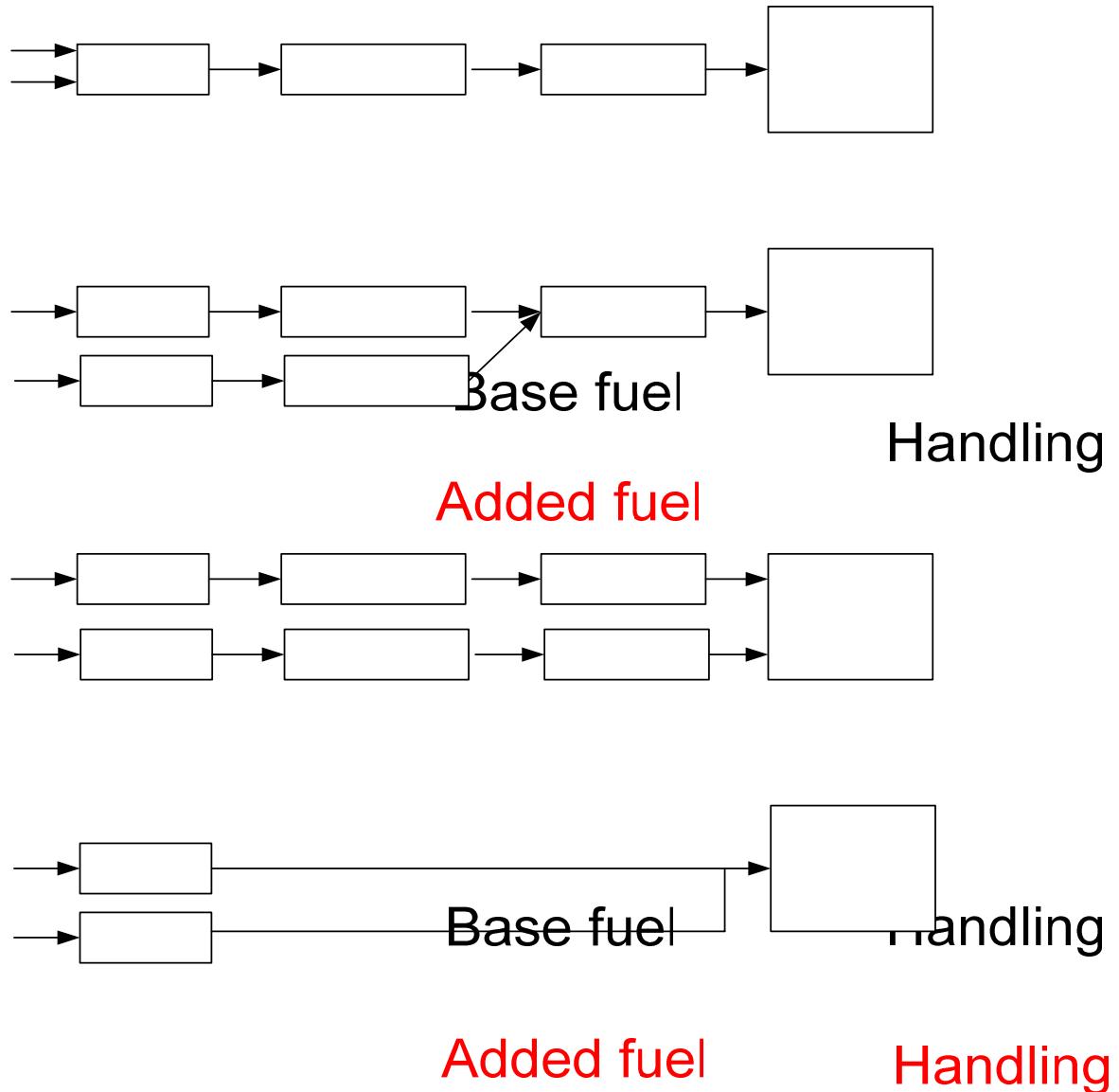


# a) TOGETHER WITH THE BASE FUEL (PC AND FBC)

Example: The power plant in Heilbronn, Germany,  
coal/municipal sewage sludge, 760 MW<sub>e</sub>, max 4%)

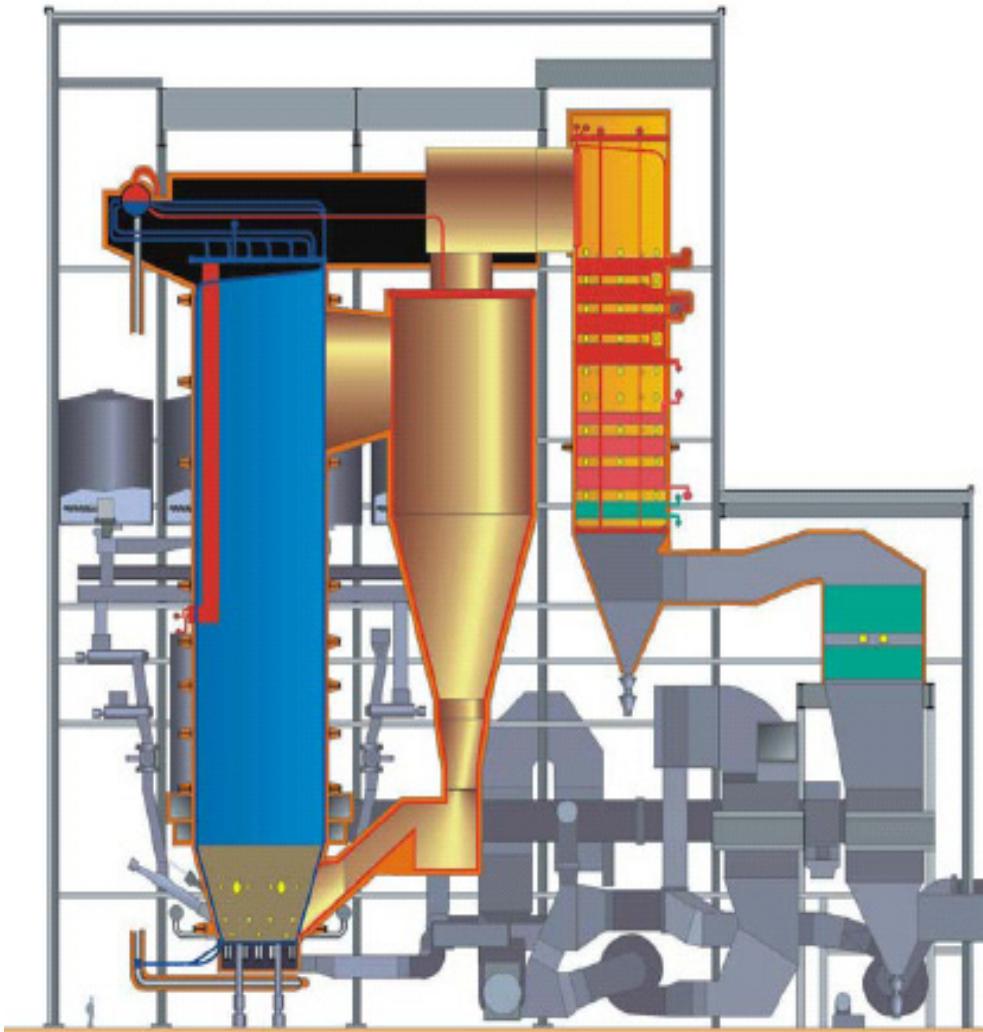


# Variations of a) for co-firing in PC and FBC boilers



# Alholmen, Finland

(Manufacturer: Kvaerner Pulping OY)



Turbine	
Live steam	194 kg/s, 162 bar, 545°C
Reheat	177 kg/s, 37 bar, 545°C

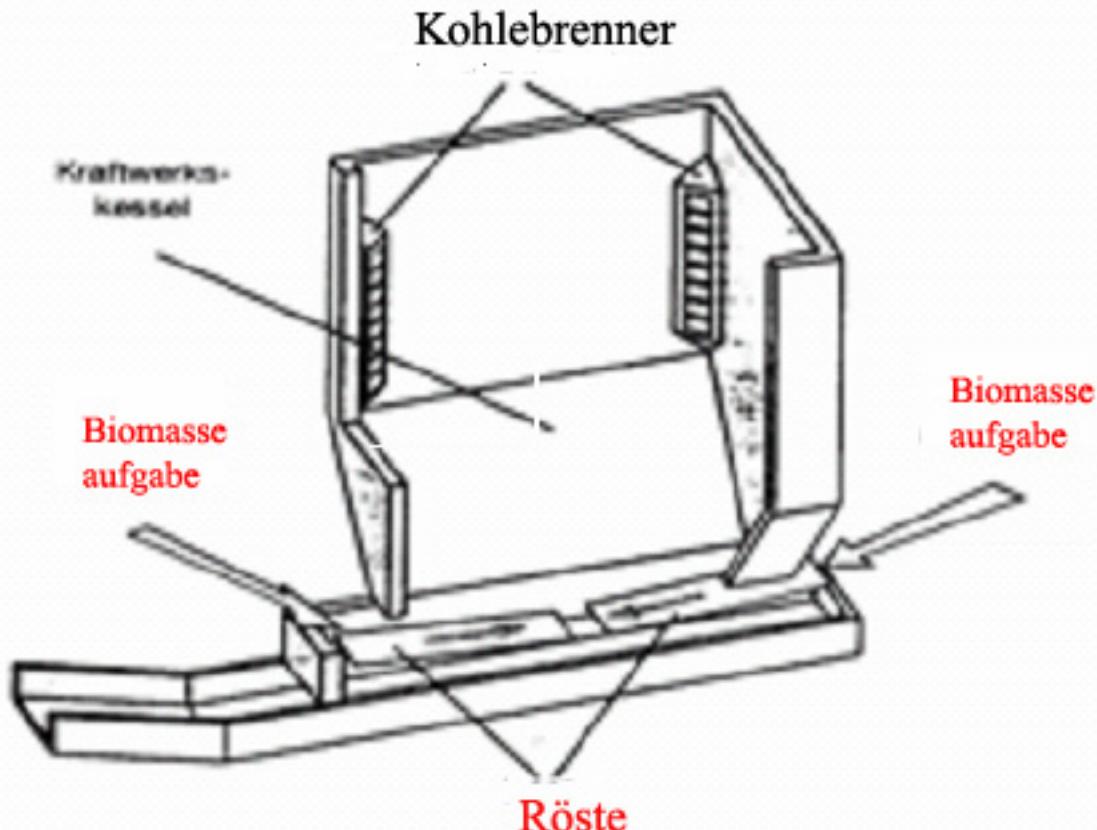
Power	240 MW <sub>e</sub>
Capacity to produce process steam	100 MW <sub>th</sub>
District heating capacity	60 MW <sub>th</sub>

Annual fuel consumption	3500 GWh/a
Fuel	Source
Wood based fuels	Pulp and paper mill
Sawing and forest residues	Sawmills within short distance, forestry sector
Peat	Production sites close to the plant
Coal or oil	Imported fuel, mostly for start-up or support fuel
	10%

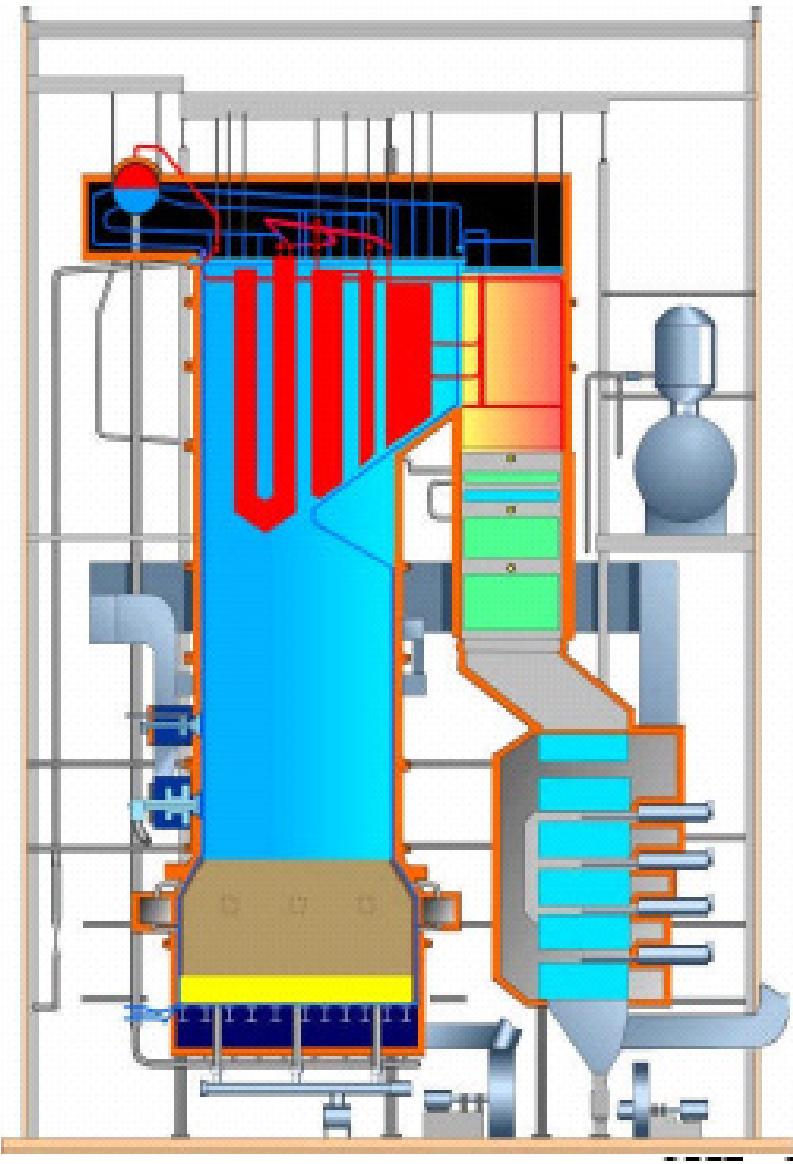
## b) ADDITIONAL BED TO A PC/GAS/OIL-FURNACE

St Andrä, Austria (124 MW<sub>e</sub>, 2x5MW<sub>th</sub>=22m<sup>2</sup> )

### COFIRING ON GRATE



## b) FB/Pulverised fuel boiler at Kaipola paper mill



Not circulating bed!

Boiler output: 104 MW

Supplier: Kvaerner (Metso)

Fuels: Sludge, bark, peat and  
coal (max 50%)

# c) PARALLEL BOILER FOR GAS/STRAW-WOOD AVEDÖRE, DENMARK

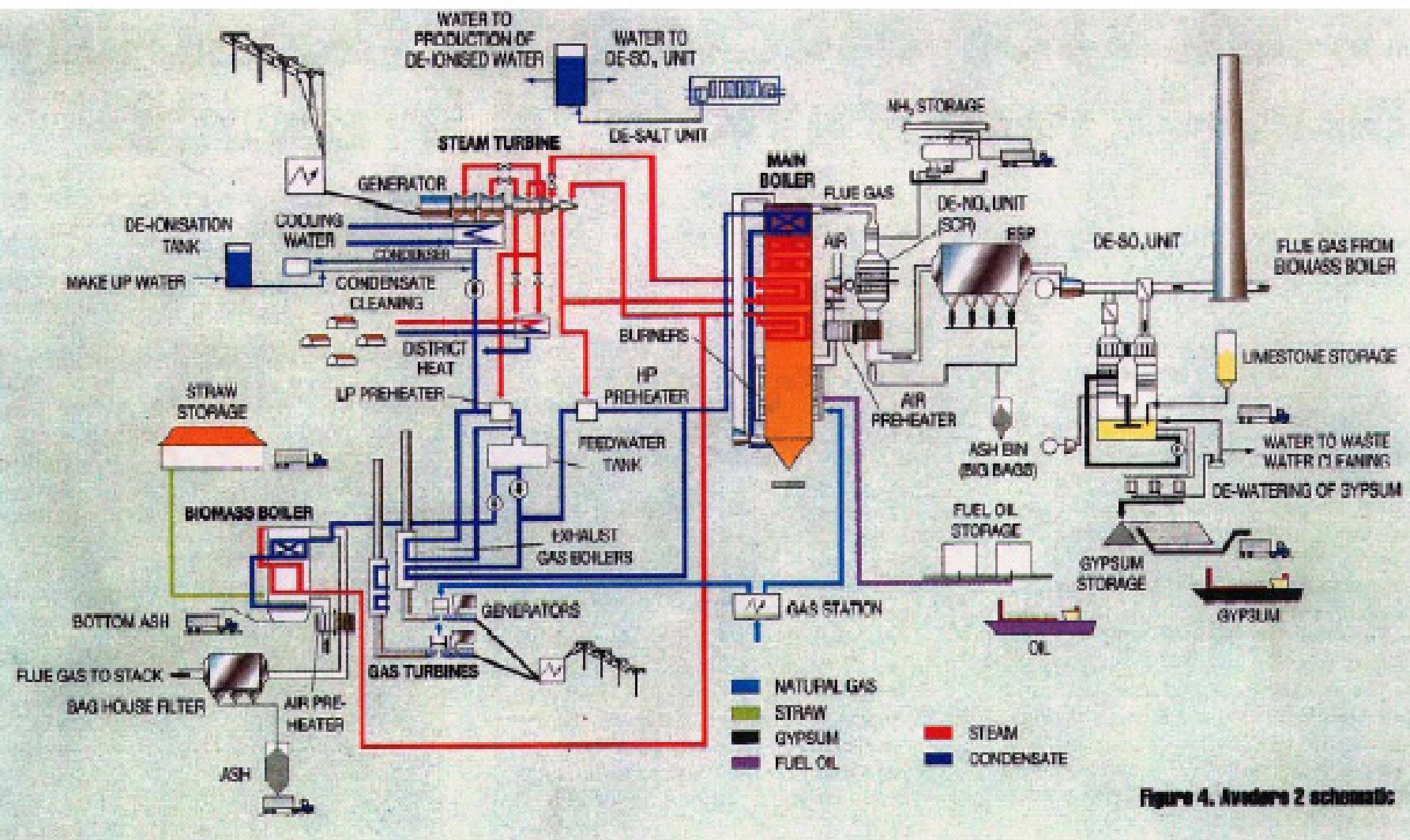
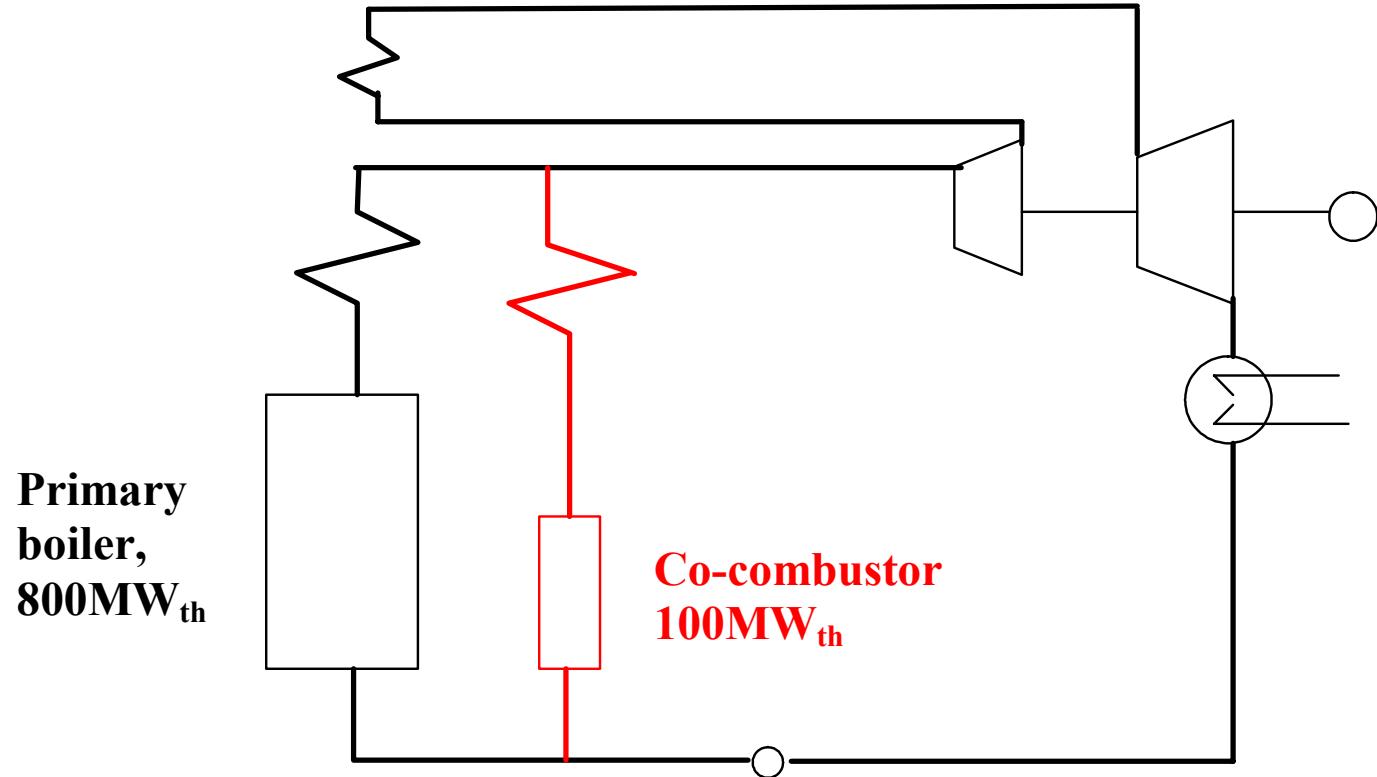


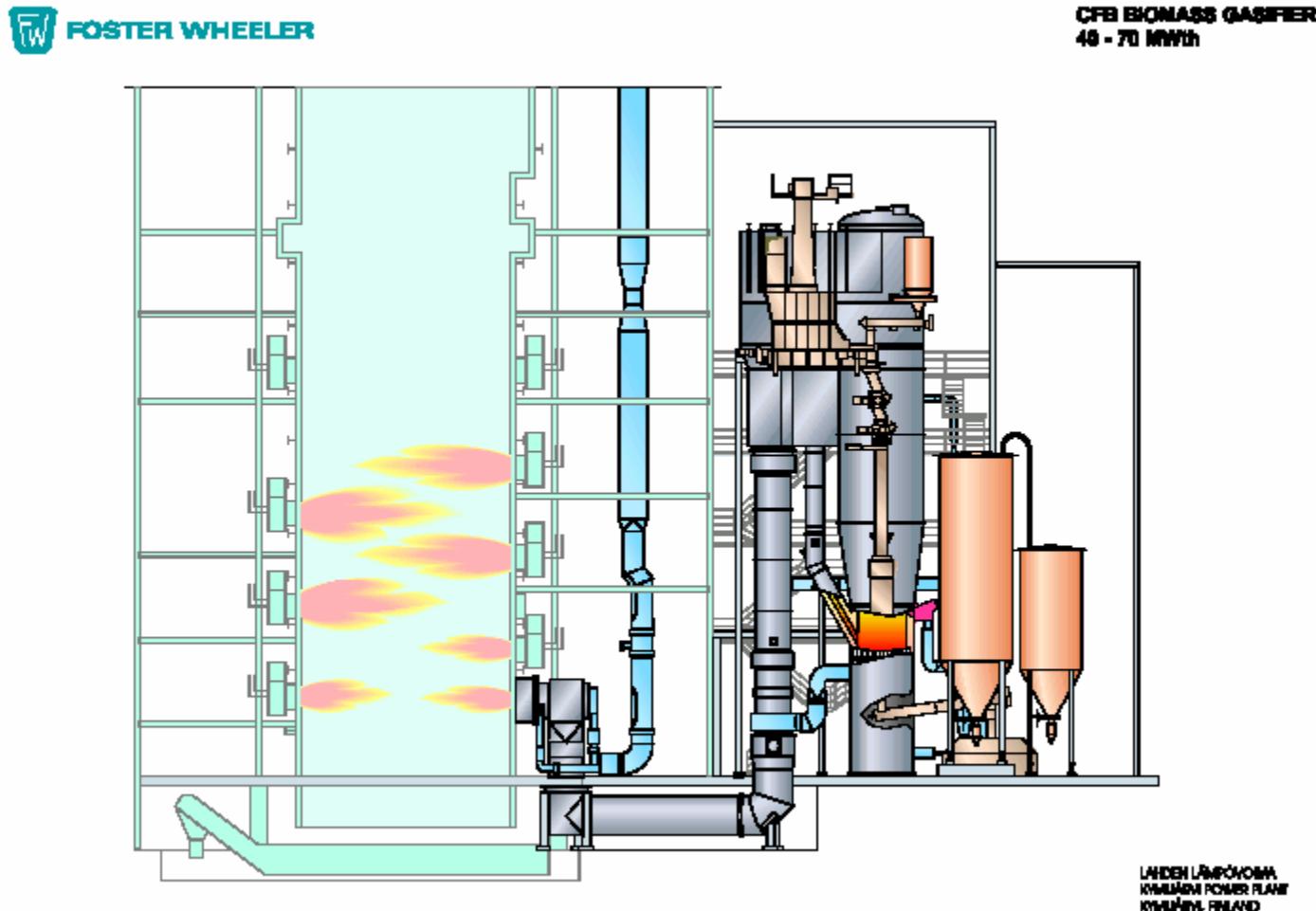
Figure 4. Avedøre 2 schematic

Figure 29. Avedøre facility schematic<sup>101</sup>  
DU LEARNER C11

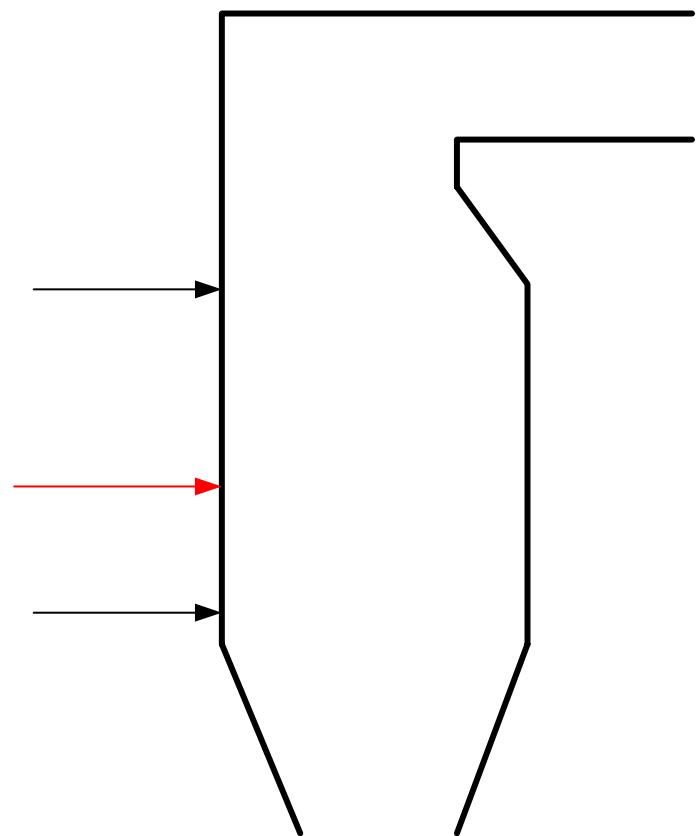
### c) PARALLEL BOILER, AVEDÖRE, DENMARK



# d) ADDITIONAL COMBUSTOR CONNECTED ON GAS SIDE, Kymijärvi power station, Finland (300 MW<sub>th</sub> coal, 50MW<sub>th</sub> additional gas)



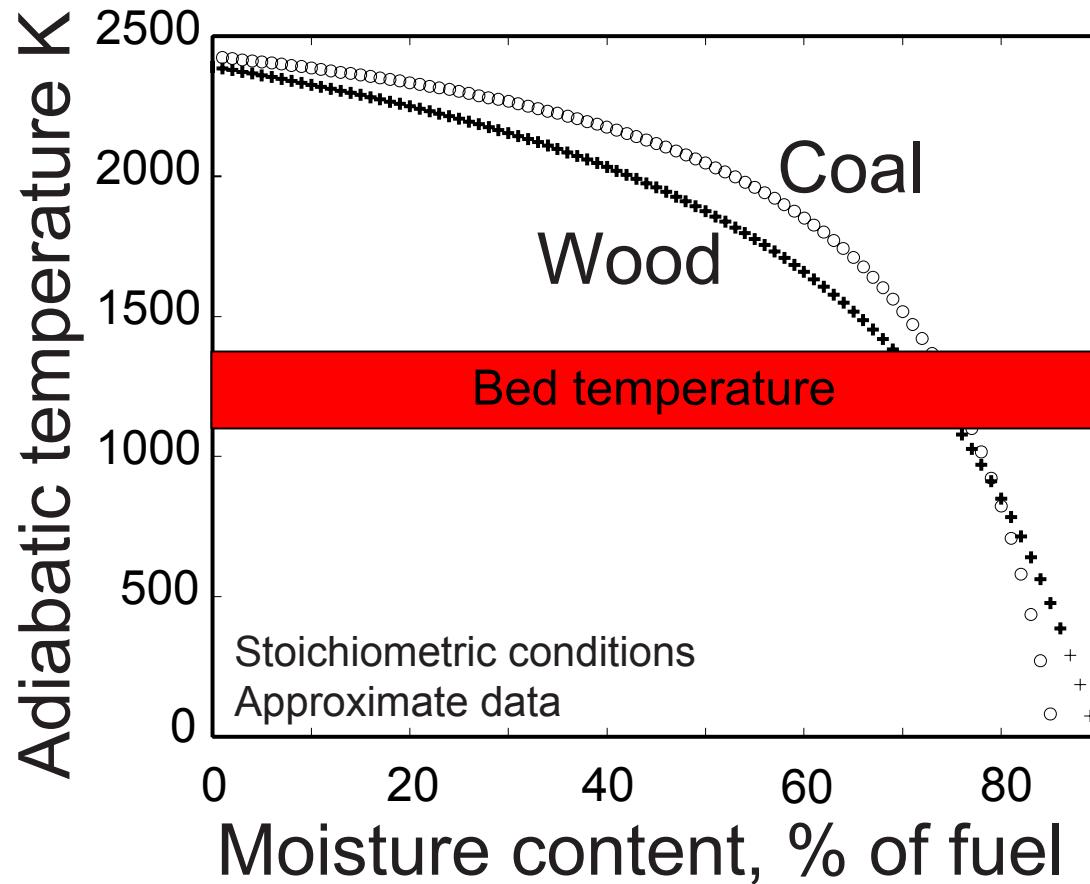
## e) REBURNING (Reduction of NO emission)



# THE CONSEQUENCES OF CO-COMBUSTION DEPEND ON FUEL PROPERTIES

1. Energy content (moisture) and volatiles. **Heat balance of a furnace. Combustion conditions**
2. Precursors to gaseous emissions (N,S,Cl).  
**Emissions, including dioxin**
3. Ash-forming elements (K,Na,Ca,Mg,Al,Si,P).  
**Deposits on tubes and corrosion**
4. Trace elements (As,B,Cd,Hg,Pb,Se,....). **Emission of volatile compounds, deposition of ashes**

# 1. THE HEAT BALANCE OF AN FB

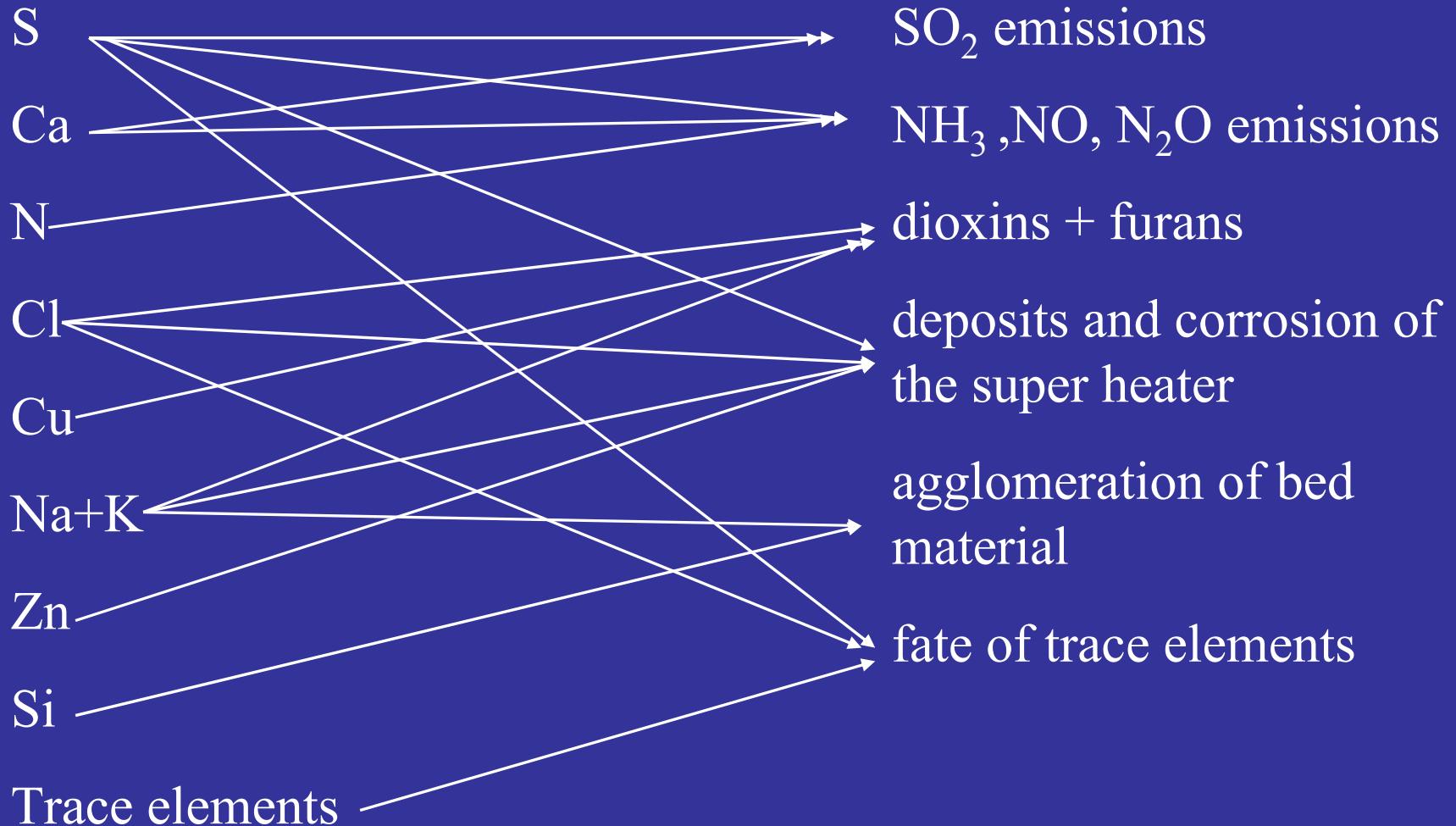


## 2-4. COMPOSITION OF FUELS

Parameter	Coals	Biofuels	Wastes
Sulphur	<b>Medium to high</b>	Low	Low to medium
Chlorine	<b>Medium</b>	Low to medium	<b>Medium to high</b>
Potassium	Medium (bound)	<b>Medium to high</b>	Low
Other alkali	Normal	Low	Low to normal
Alumina, silica	High	Low to high	High

# Synergy effects

Fuel property



# Options

A judicious choice of fuel combinations may have advantages:

- Dioxin formation may be avoided
- Sintering and deposits may be avoided
- Emissions can be affected

## 2. CONDITIONS FOR FORMATION OF DIOXIN/FURAN FROM COMBUSTION

- Presence of chlorine
- Inadequate combustion conditions
- Insufficient residence time above 800 °C
- Presence of catalyst surfaces at 250-450 °C

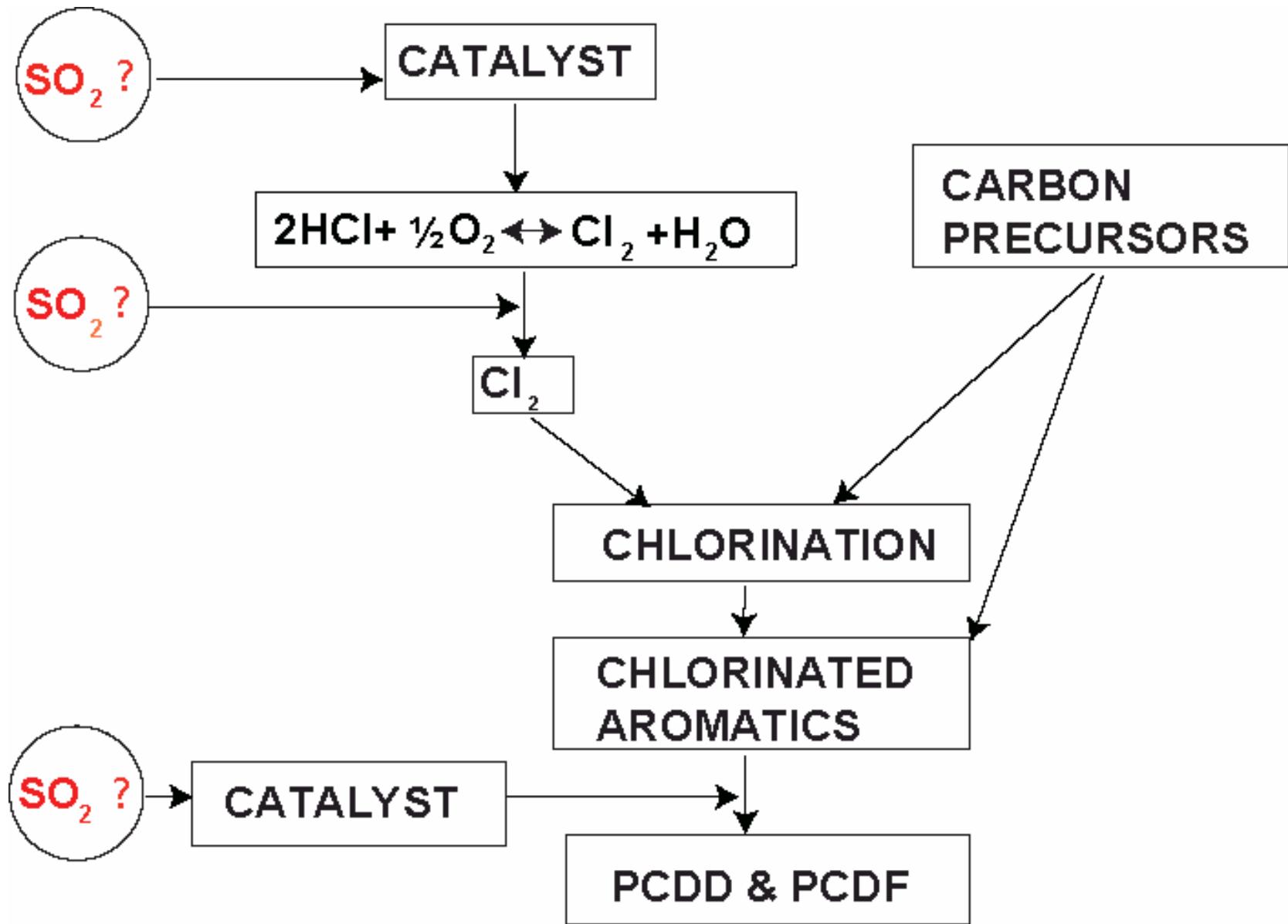
# SYNERGY EFFECTS INVOLVING COAL

The dioxin emission from coal-fired boilers is surprisingly small. Griffin (1986) therefore suggested



removing chlorine from formation of dioxins and furans

- Will reaction (2) prevent formation of precursors?
- Will the catalysts, for instance copper, be sulfated and thereby their activity will be reduced?



# CONCLUSION ON THE EFFECT OF S ON DIOXINS

The results from several large-scale tests claim that sulphur has a beneficial effect on the reduction of dioxins, but the documentation of the tests is not convincing.

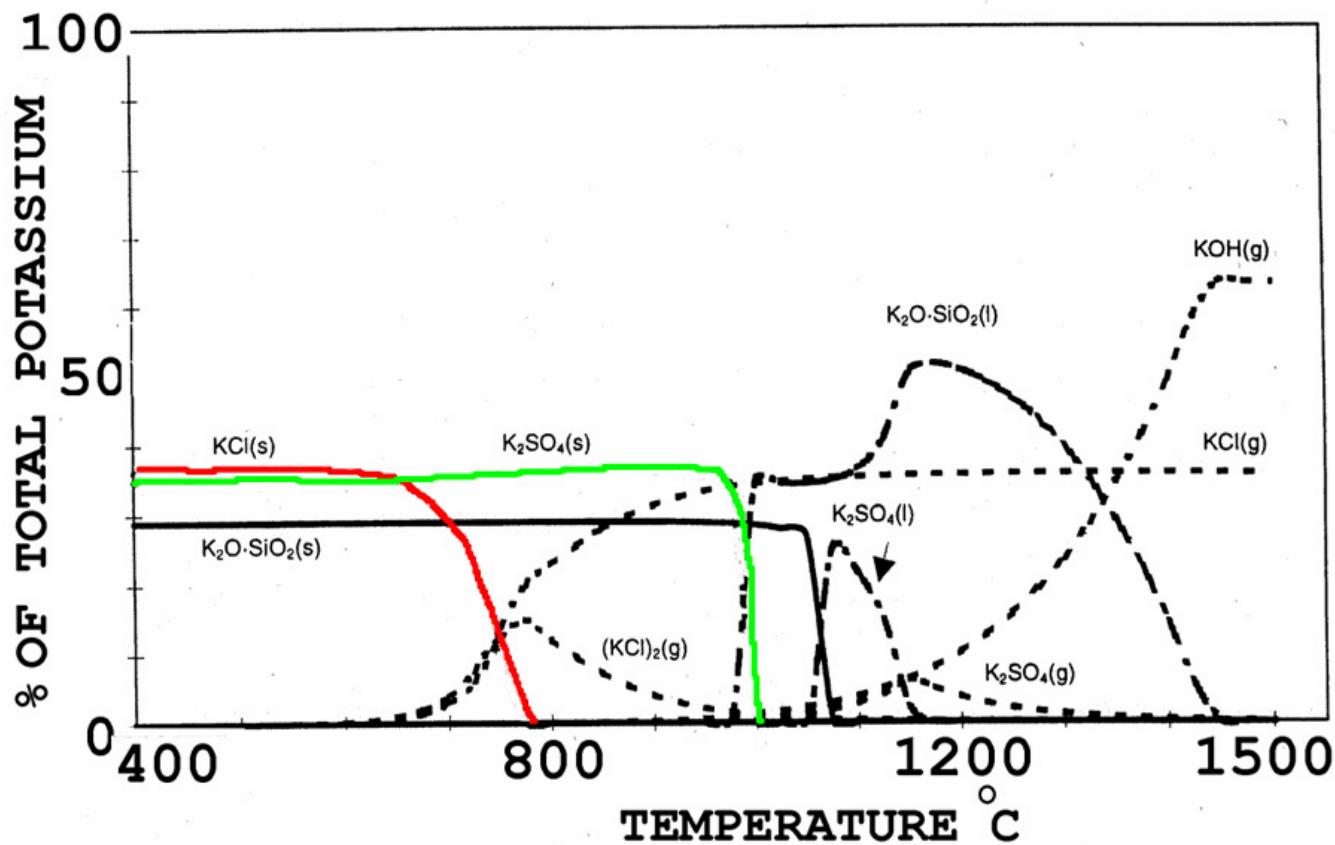
## 2,3. DEPOSITS & CORROSION

Influencing factors:

- Tube surface temperature, material and location
- Gas temperature
- Fuel composition, especially ash and S/Cl ratio
- Combustion conditions, total and local oxygen availability

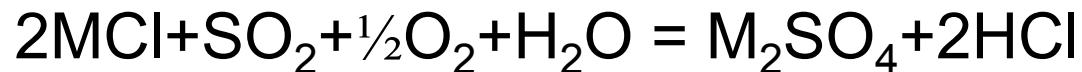
# Ash behaviour

Equilibrium calculations give an idea of the behaviour of some ash components (potassium in straw in this example) (From Nielsen et al., 2000)



# RELATION BETWEEN SULPHUR AND CHLORINE

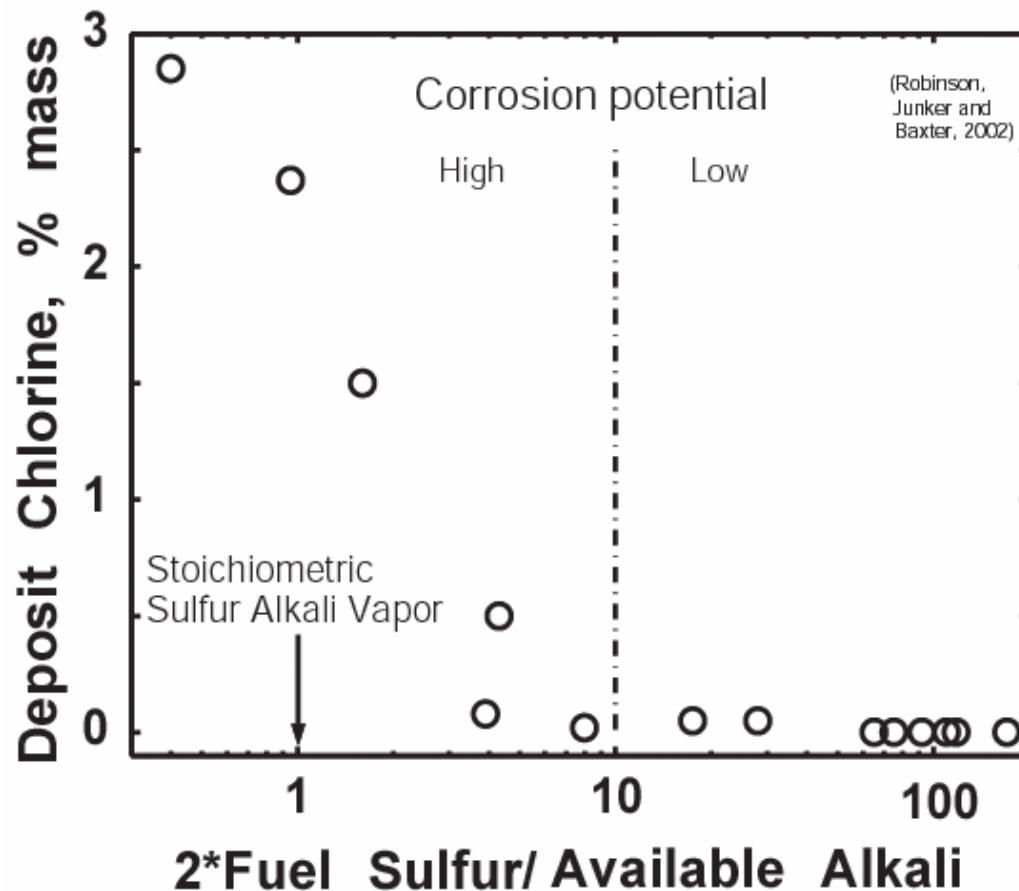
- It is often proposed that an alkali chlorid MCl reacts with sulphur to form sulphate



- At higher temperatures alkali may be bound in aluminosilicates

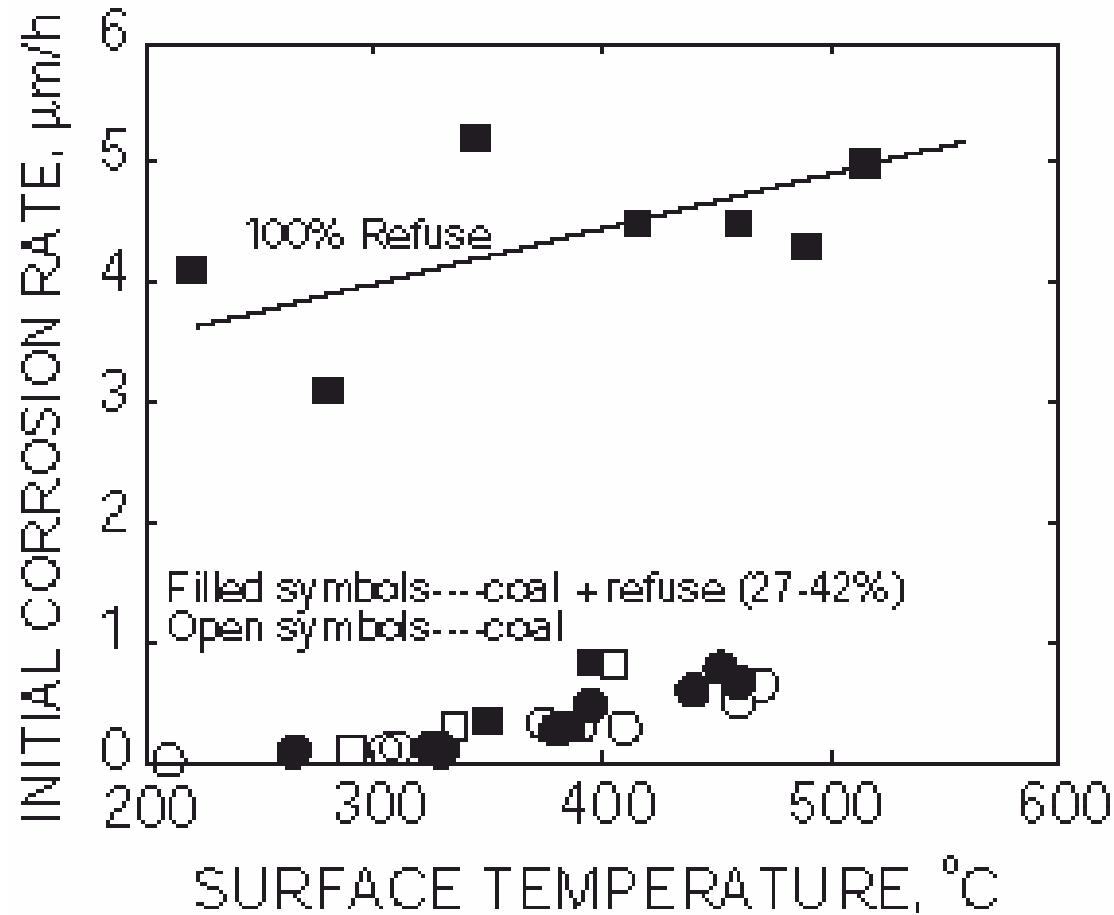
# CHLORINE IN DEPOSITS AS A FUNCTION OF SULPHUR ADDITION

(O<sub>2</sub> 3%, gas 1000 °C, probe 540 °C. Robinson et al., 2002)



# KRAUSE'S CO-COMBUSTION RESULTS (1986)

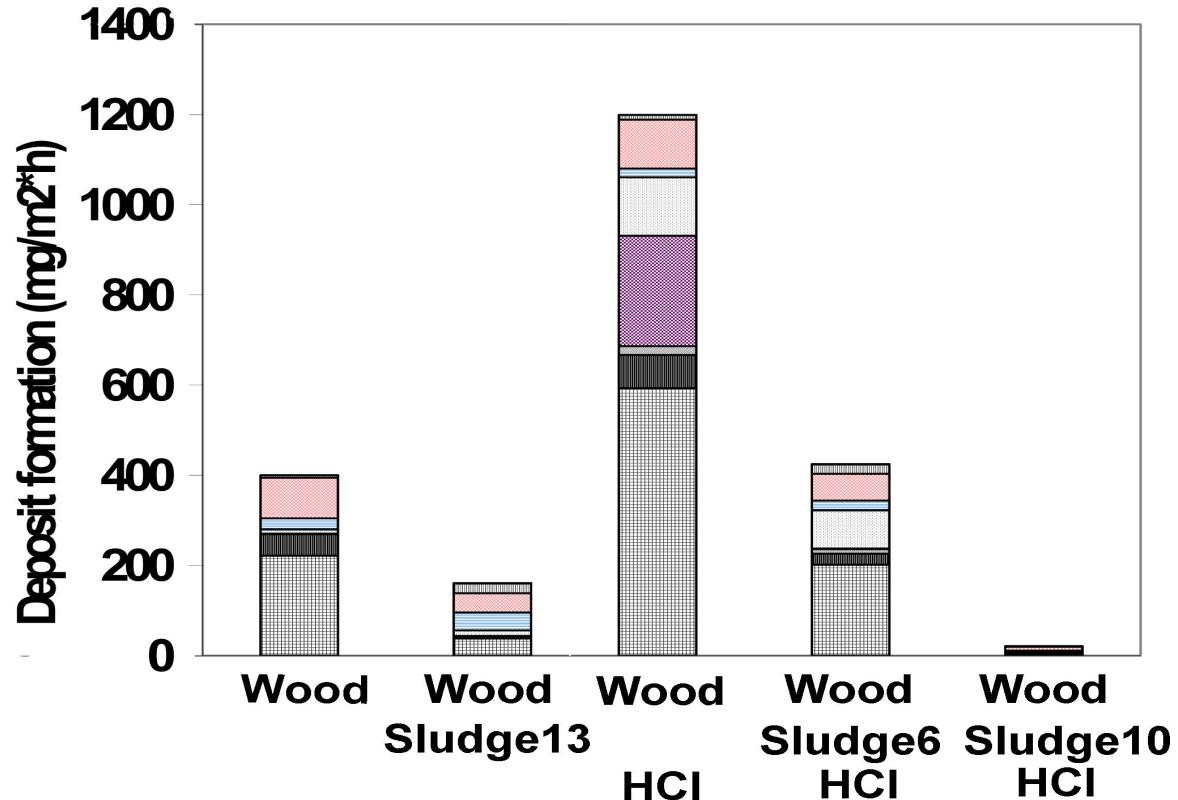
## (Waste combustion)



## OBSERVATIONS OF KRAUSE et al. (1975-...):

- Conversion of chlorides to sulphates by  $\text{SO}_2$  in waste incinerators **reduces** serious corrosion.
- The impact of chlorine on corrosion can be reduced by increasing available sulfur  $\text{S}/\text{Cl} > 4$ .
- Sulfur can be added directly or by co-combustion with coal.

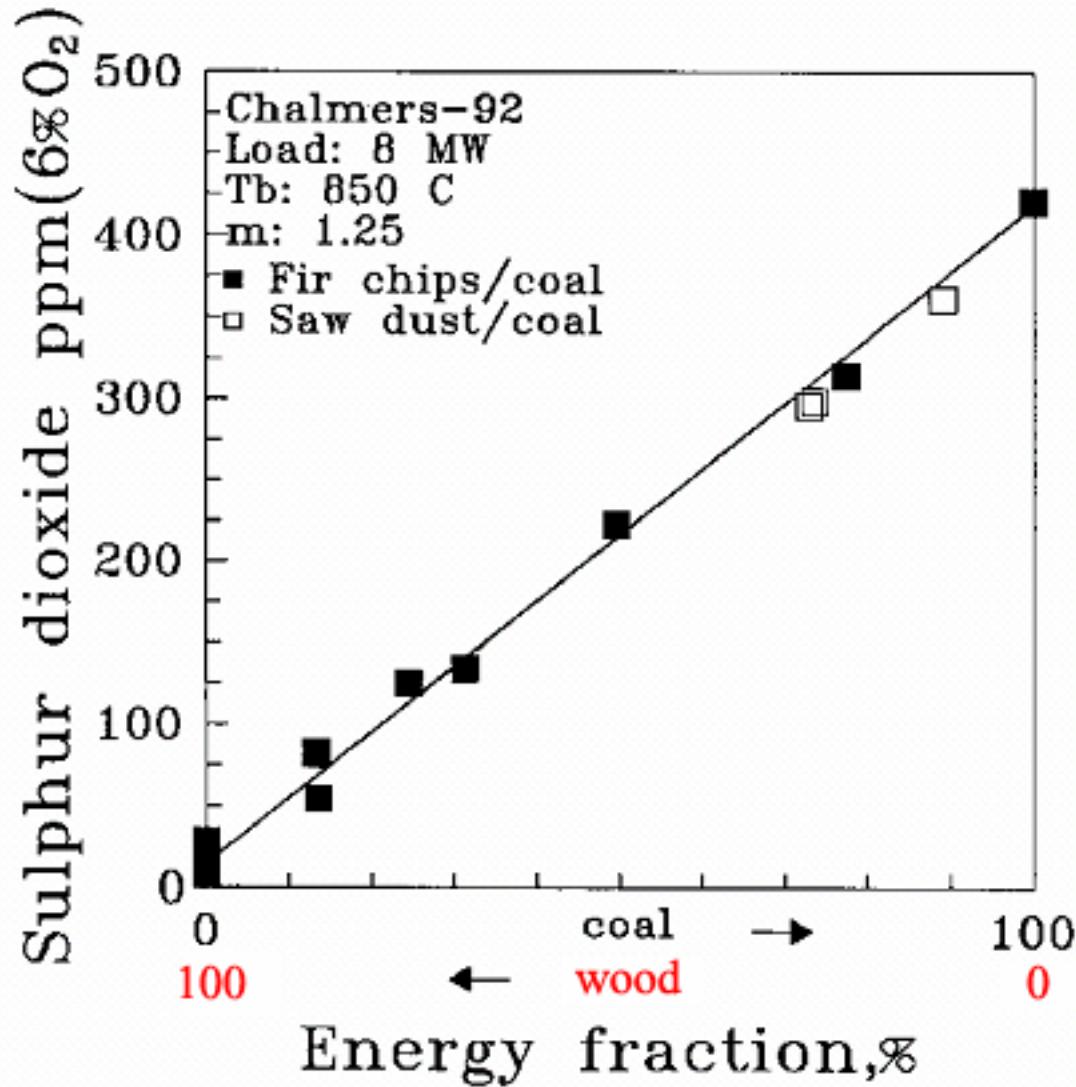
# INFLUENCE OF CHLORINE AND SLUDGE ON DEPOSITS FROM WOOD



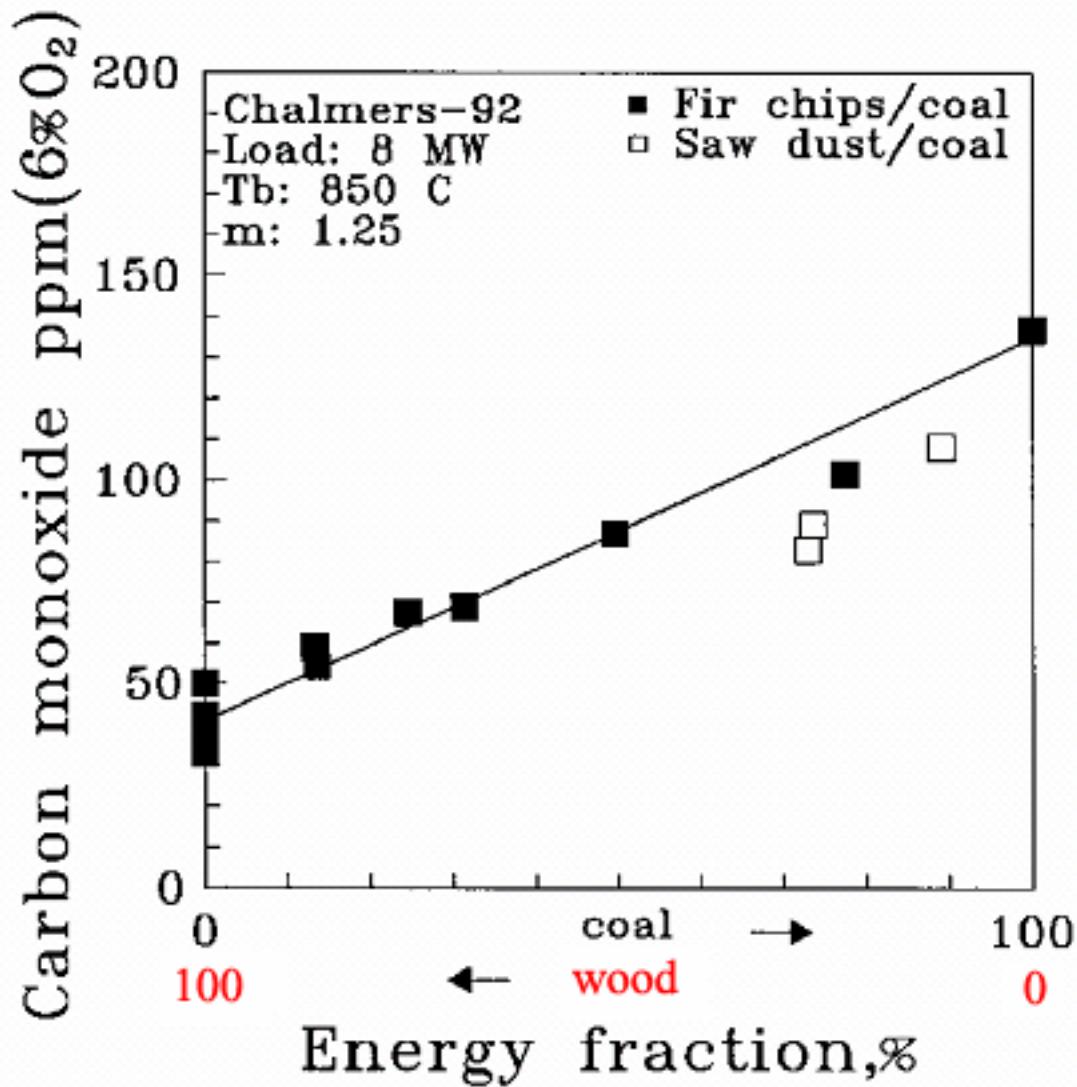
(Åmand et  
al. 2007)

## 2. Precursors to gaseous emissions in fluidized bed (N,S,Cl)

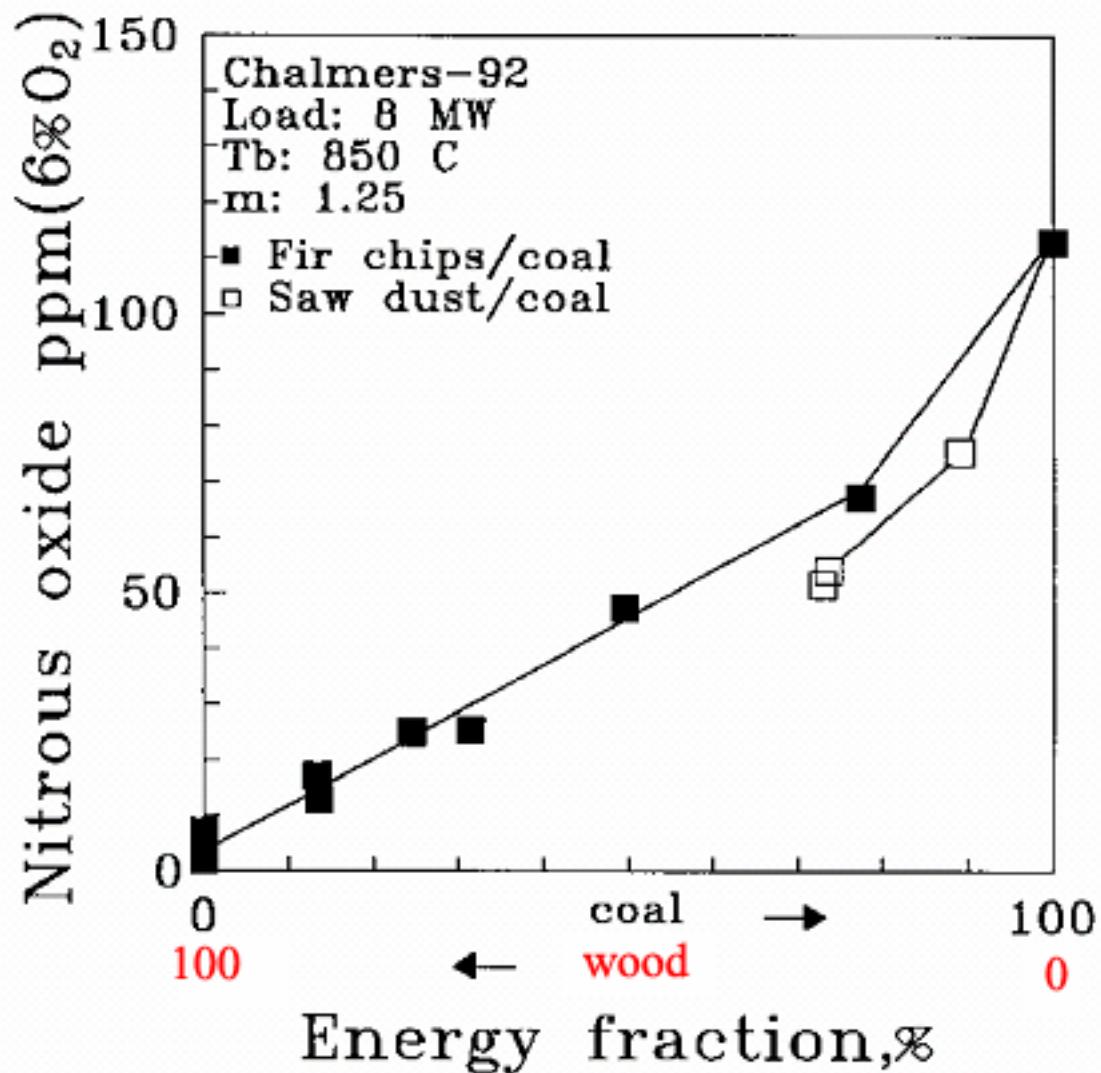
# SULPHUR EMISSION (CFB)



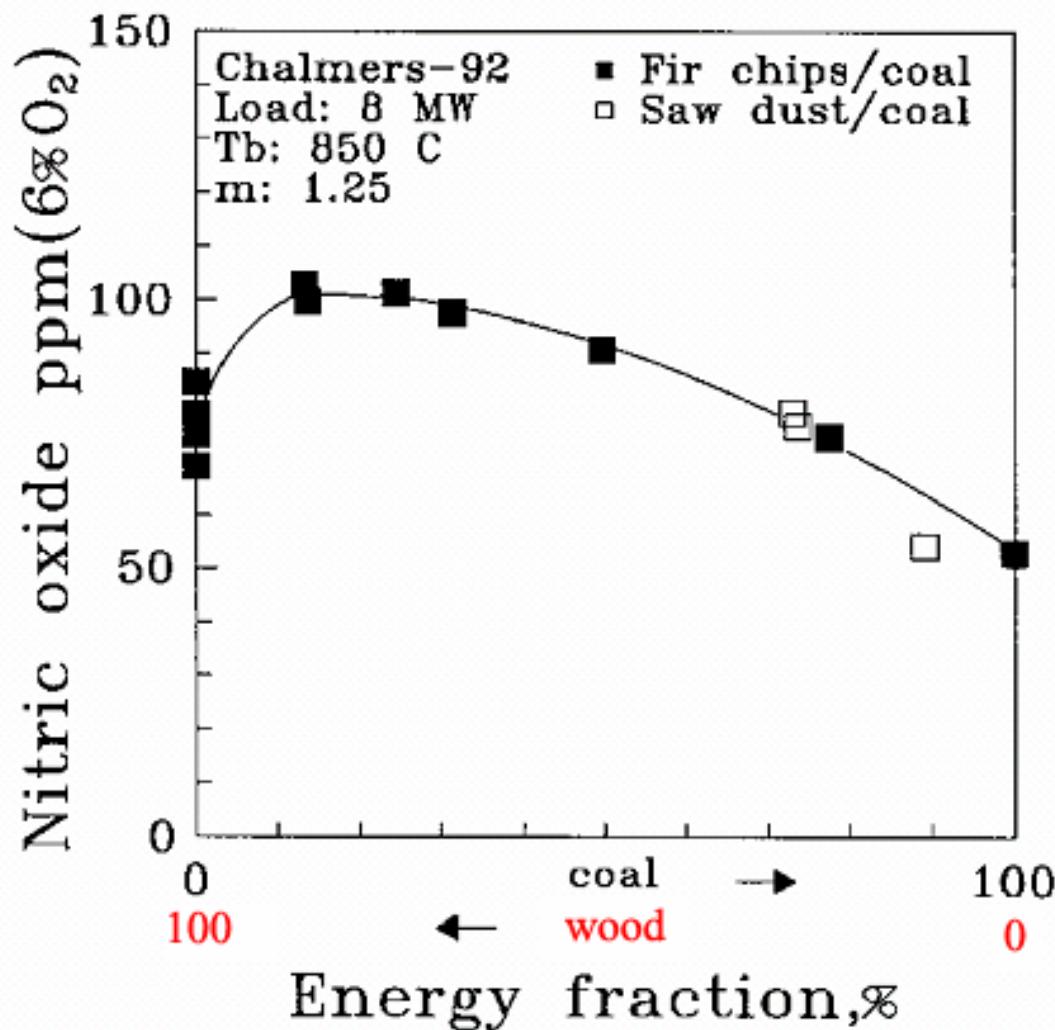
# CARBON MONOXIDE EMISSION (CFB)



# NITROUS OXIDE EMISSION (CFB)



# NITRIC OXIDE EMISSION (CFB)



# CONCLUSIONS ON SYNERGY EFFECTS

- Emissions of  $\text{SO}_2$ ,  $\text{NO}_x$  and CO are only moderately influenced by synergy
- Sulphur may have a decisive influence on dioxin emission
- Sulphur, chlorine, potassium and Al-Si influence deposits on tubes
- Etc—there are several other synergy effects that also need to be further investigated

# ADVANTAGES OF CO-COMBUSTION

- It is the cheapest method available for CO<sub>2</sub> reduction from energy conversion of fuels
- It is cheaper than monocombustion of biofuels
- Wastes can be utilized
- Biofuels and wastes can be converted at a high efficiency and with efficient flue gas cleaning
- There may be positive synergy effects
- Seasonal variations in the supply of additional fuels can be handled, and the impact of quality variations can be mitigated

# DISADVANTAGES OF CO-COMBUSTION

- The additional fuel ash can make secondary utilization of ashes less favourable.
- Biofuels can be more expensive than coal
- There may be negative synergy effects
- Lack of experience, particularly in case of extreme steam data
- Inactivation of SCR catalysts could occur

# CO-COMBUSTION PROPERTIES OF CFB

- + Independent of the fuel mix as long as the thermal balance of the furnace is fulfilled
- + No problems with grinding and preparation of the fuel, but fuel transportation systems of the plant must be adapted.
- + CFB is a chemical reactor where synergy effects can be exploited
- + Most mentioned advantages and disadvantages are valid for CFB
- CFB is not yet developed in large utility scale