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# The FBC situation in Sweden

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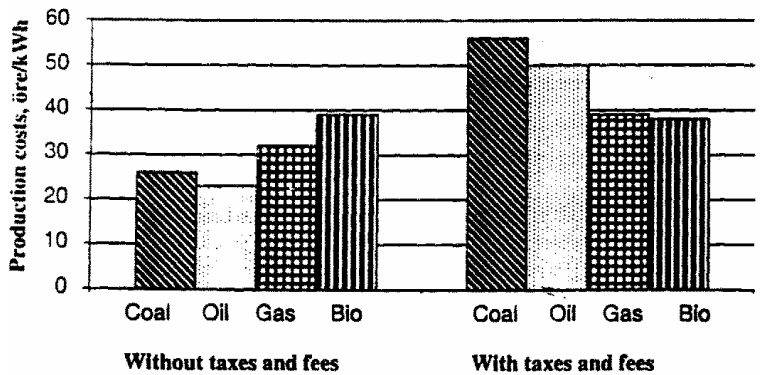
# CONTENT

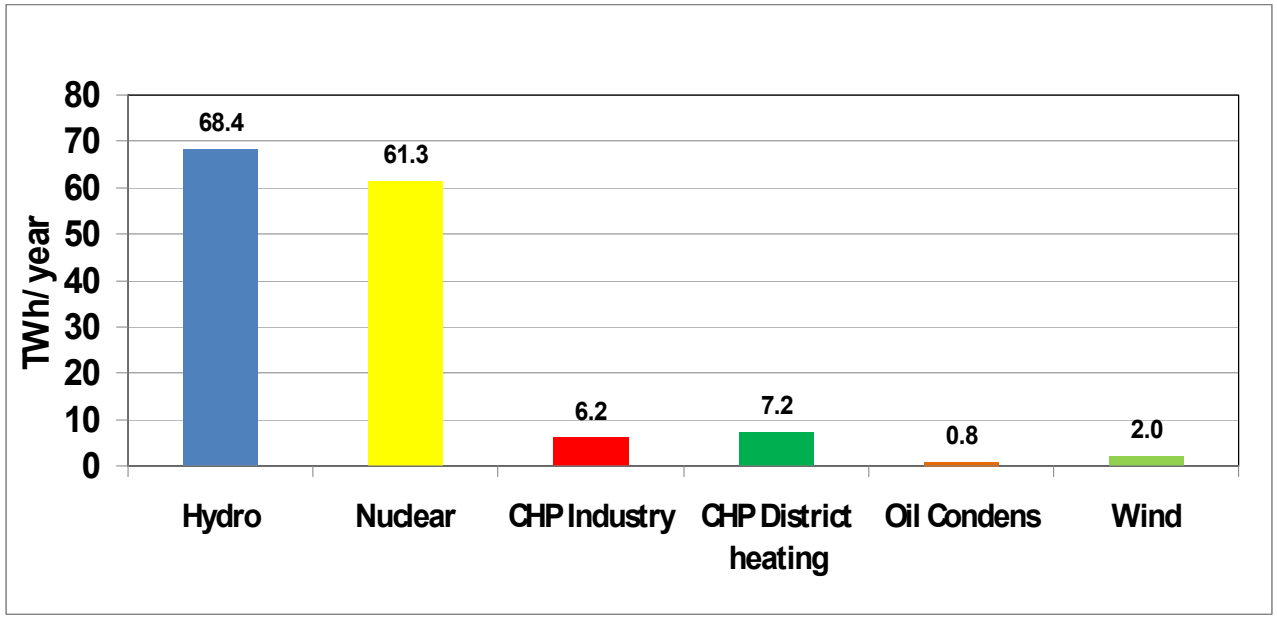
- Background: the energy situation in Sweden
- Historical aspects
- Present situation
- Research and development

# HISTORICAL ASPECTS

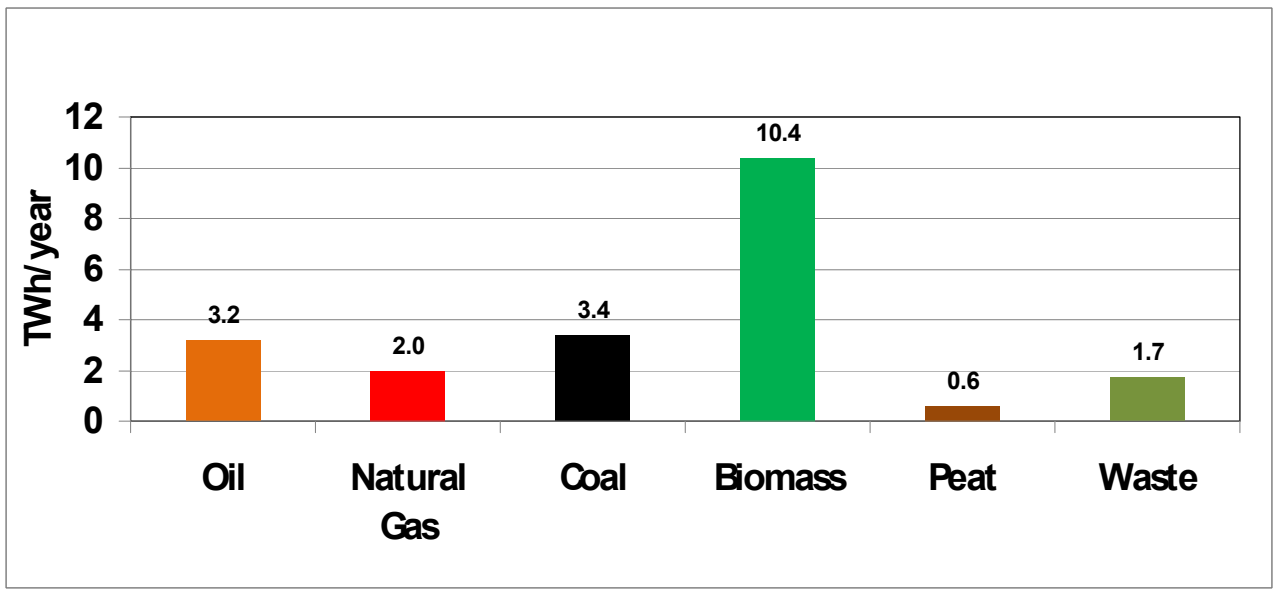
- 1972 First ”oil crisis”
- 1980 Referendum decided to phase out nuclear energy
- 1981 Investigation to show the benefits of coal
- 1995 Biomass preferred and priviledged by taxes




- 2005 The CO2 issue becomes increasingly important

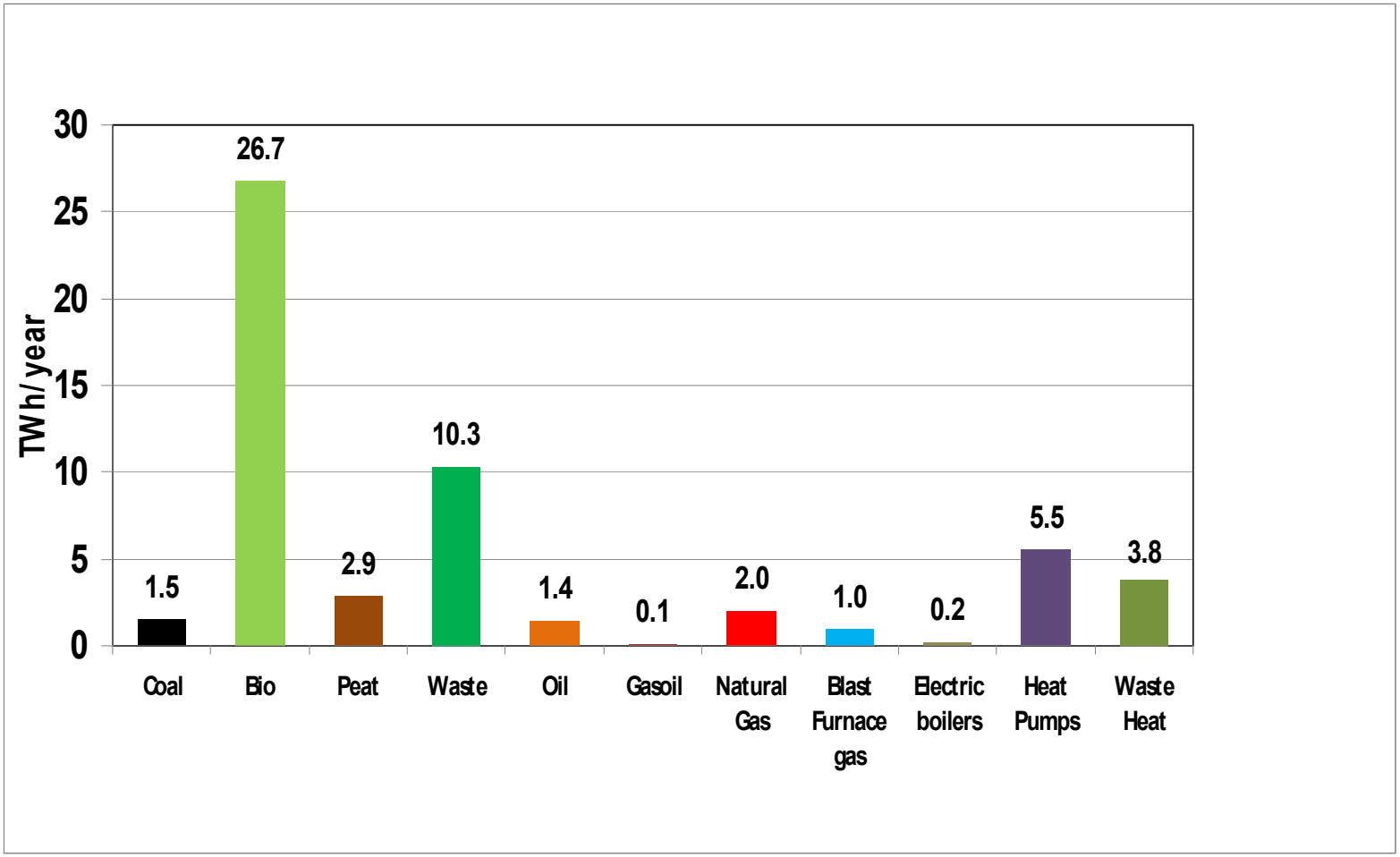



Power generation in Sweden 2008, TWh/year




Non-nuclear fuel consumption for power generation in Sweden 2008

# DISTRICT HEAT PRODUCTION 2008
## Fuel and energy sources, TWh/year



# MAJOR MANUFACTURING COMPANIES

- Götaverken
- Generator

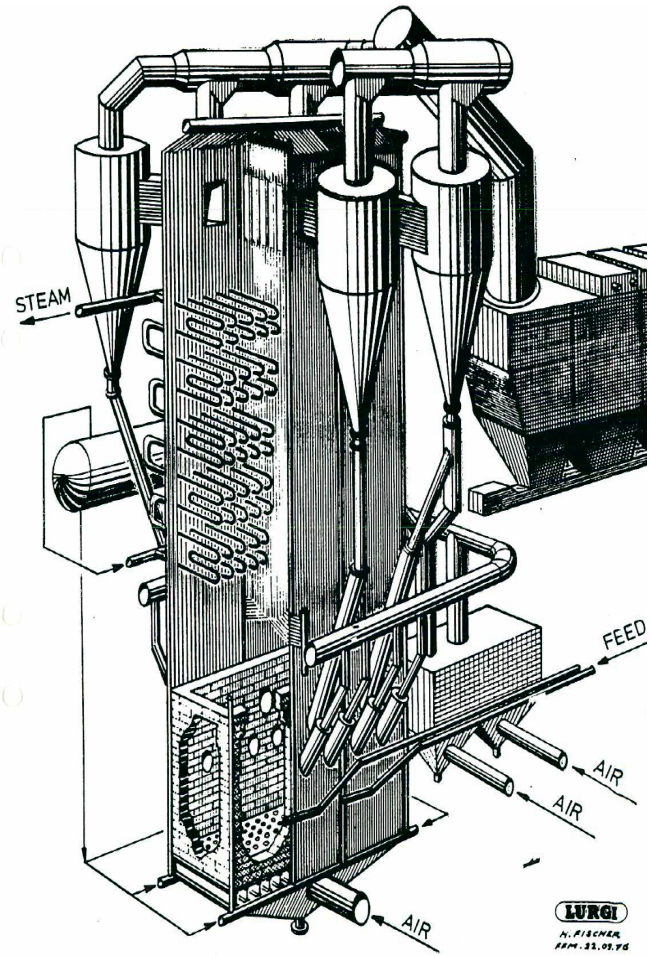
→ Götaverken-Generator→Kvaerner→Metso

- Stal-Laval (Gas turbines)

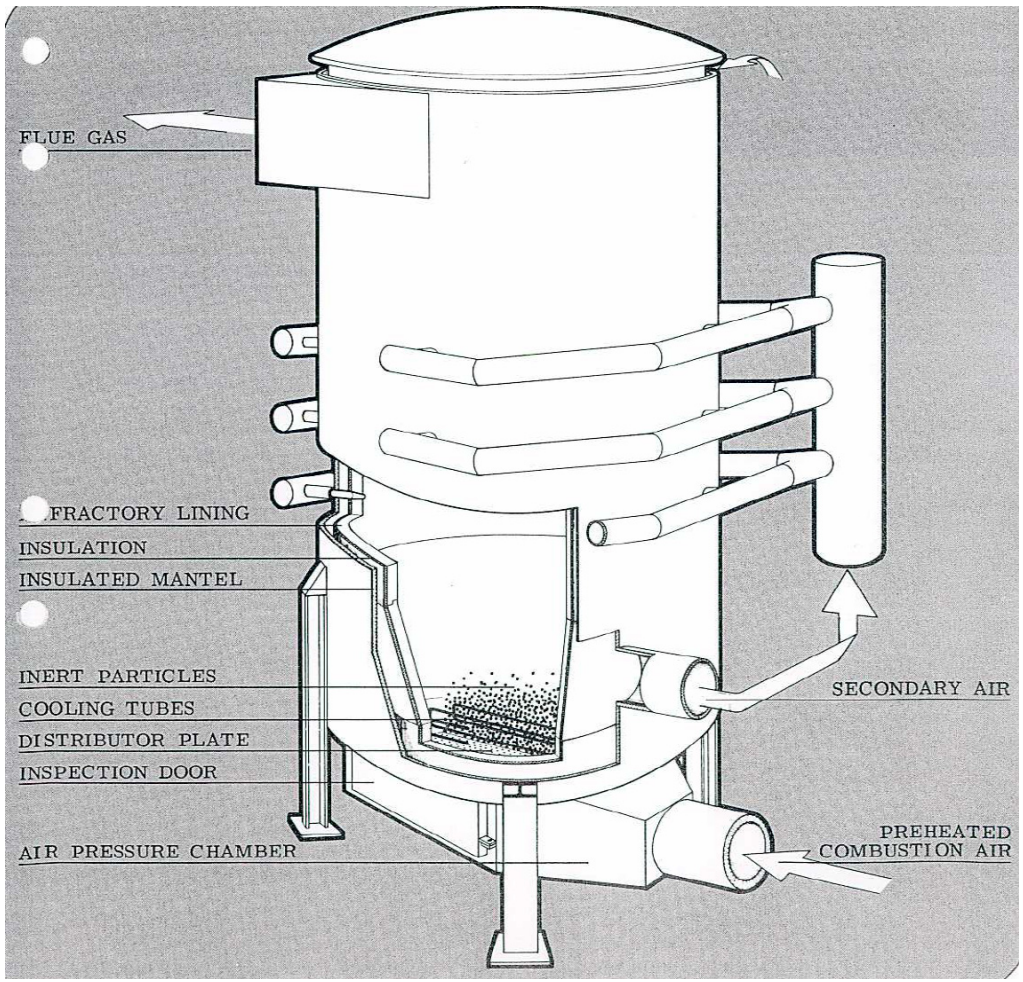
↓

- ASEA → ASEA-PFBC → ABB-PFBC → Siemens
- ASEA→ ASEA-ATOM → (Nuclear reactors)
  → (Nuclear fuel manufacturing)

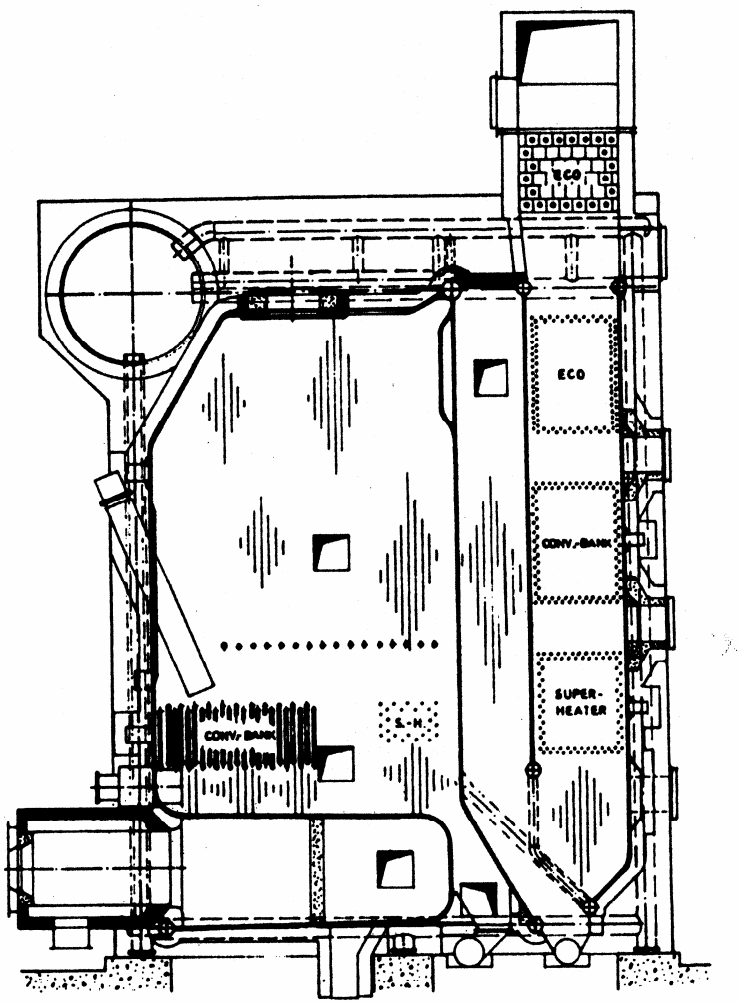
# CFB BOILER FOR THE TREATMENT OF IRON ORE, PROPOSED TO BURN SHALE IN RANSTAD IN THE 1970's



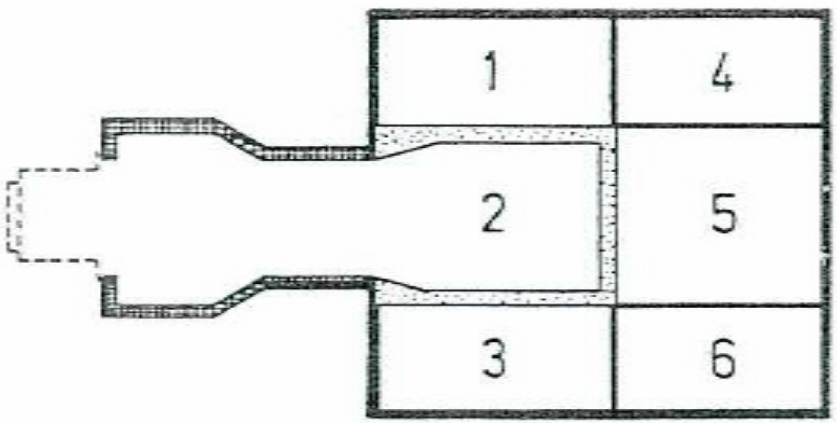
# THE FIRST FBC BOILER BUILT IN SWEDEN 1977 ---A COMPLETE FAILURE (25 $MW_{th}$)



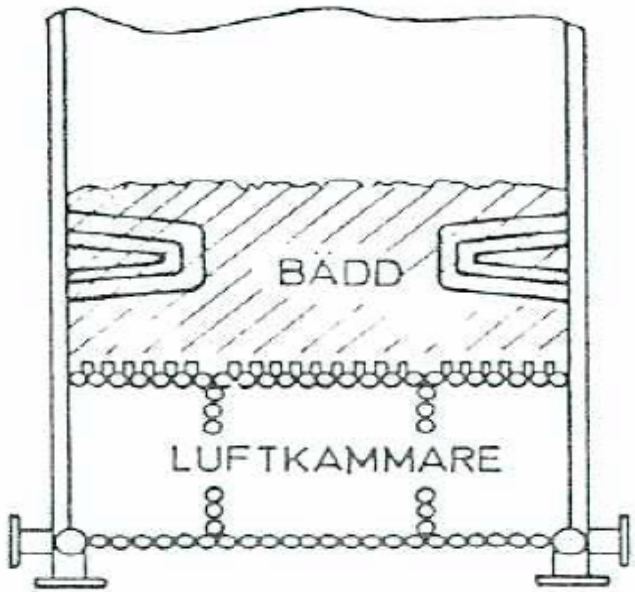
# THE 16 MW FBC BOILER AT CHALMERS UNIVERSITY, 1982-1989 [2]



# THE 16 MW FBC BOILER AT CHALMERS UNIVERSITY, 1982-1989, Some design details [2]

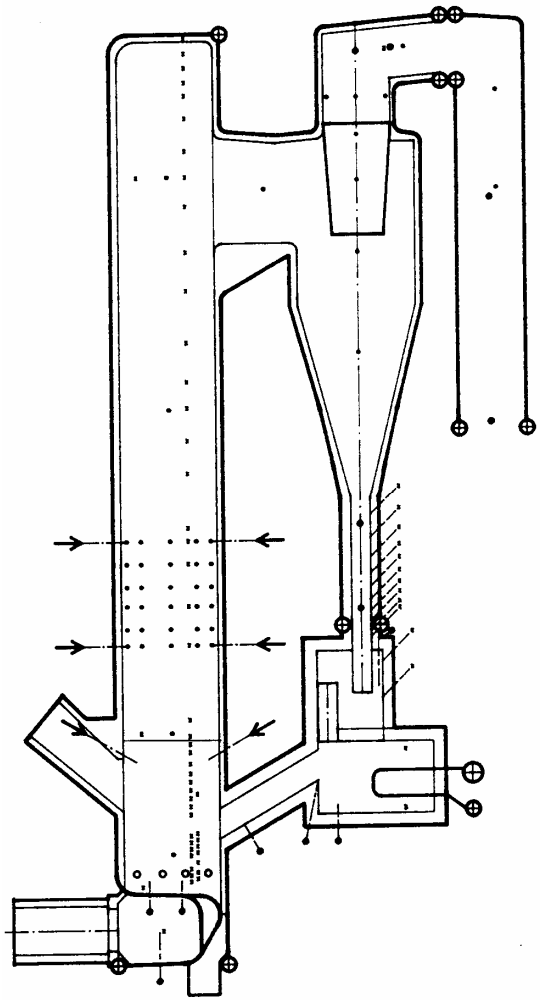



Horizontal cross-section of the air plenum with the start-up combustor

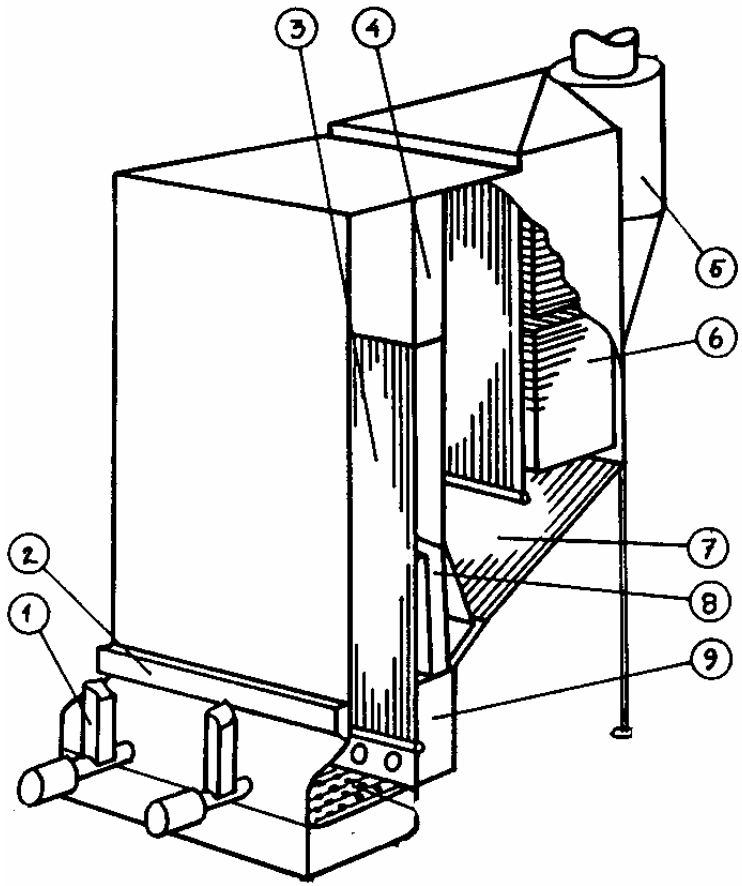



Vertical cross section through bed and air plenum

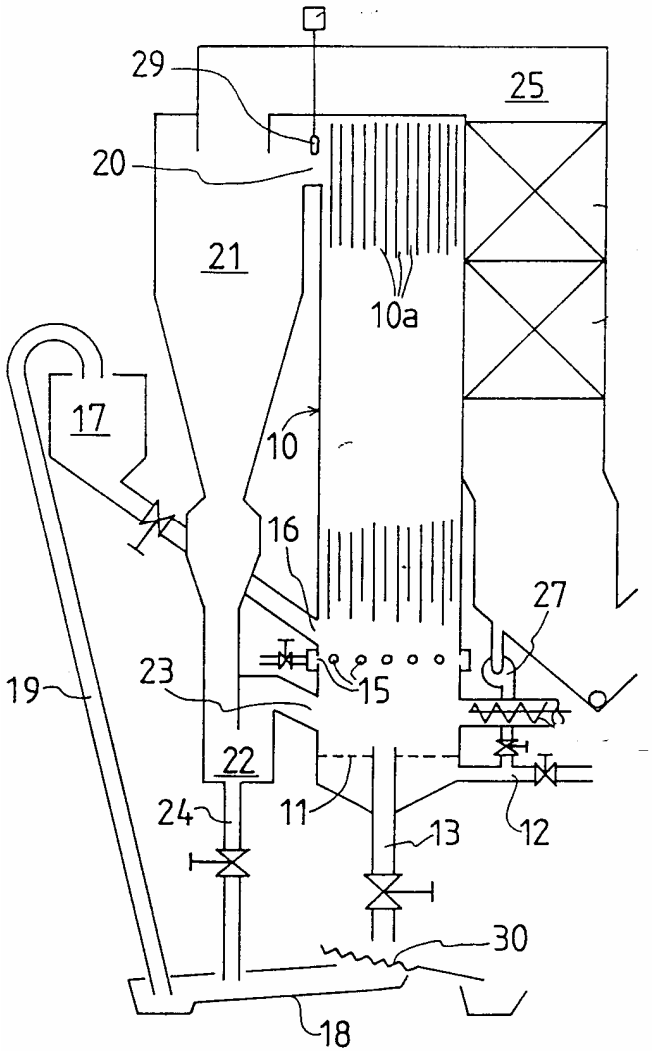
# THE 12 MW CFB BIOLER AT CHALMERS UNIVERSITY, 1990- [3]



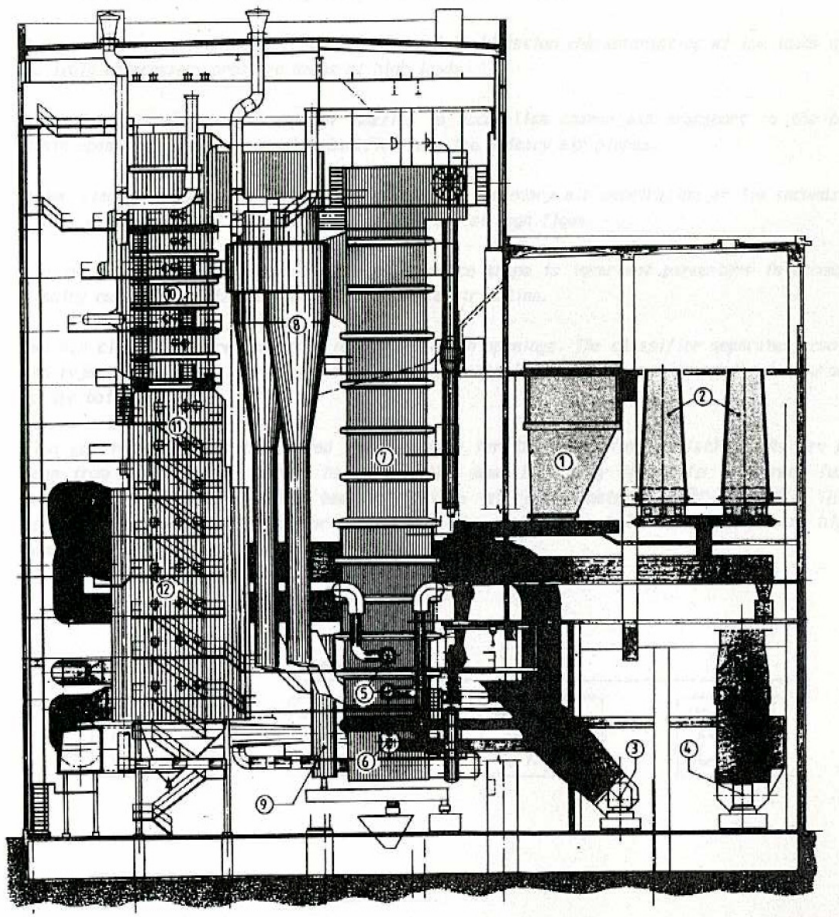
# A 35 MW CFB boiler based on the Studsvik prototype [4]



# Principle drawing of Götaverken's CFB boiler taken from a patent application 1985 [5]



# ÖREBRO 165 $MW_{th}$ CFB boiler 1988 [6]



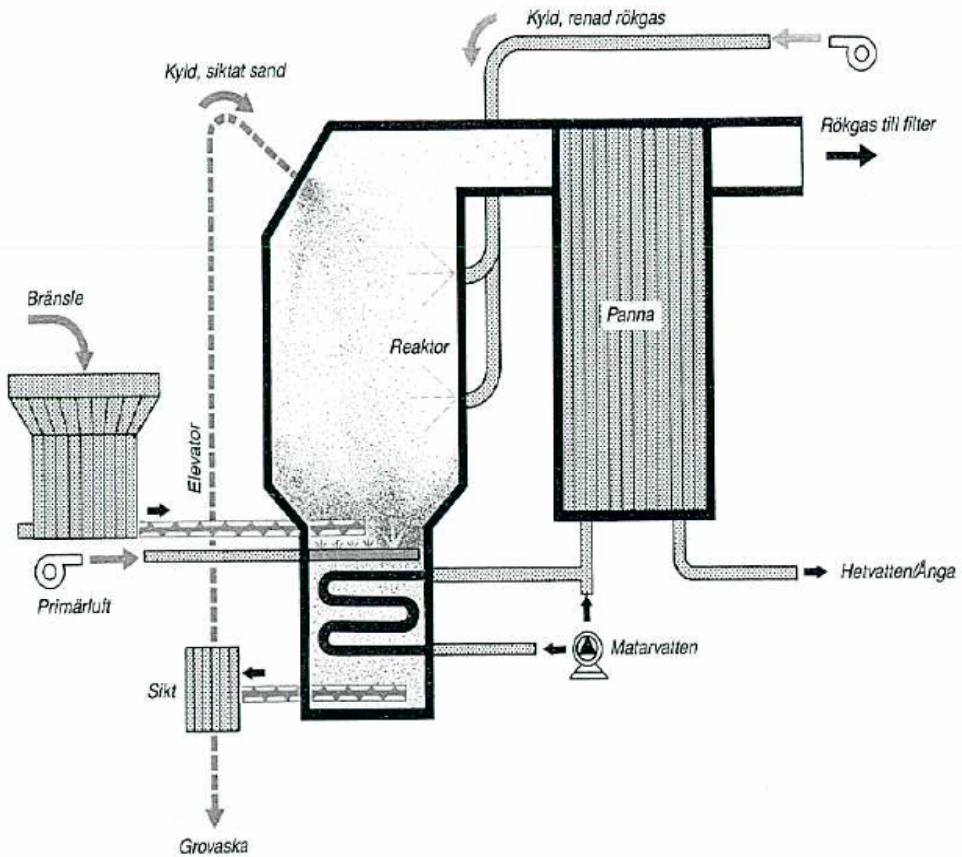
| | | | |
|---|---|---|---|
| 1 | COAL SILOS | 7 | FURNASE |
| 2 | BIOMASS SILOS | 8 | HOT GAS CYCLONES |
| 3 | TOTAL AIR FAN | 9 | ASH CLASSIFIER |
| 4 | FLUE GAS FAN | 10 | CONVECTION SUPERHEATER |
| 5 | LOAD OIL BURNERS | 11 | ECONOMIZER |
| 6 | START-UP BURNERS | 12 | PRIMARY AND SECONDARY AIRHEATER |

Built by Götaverken-Generator

Steam conditions: 150 bar/540 deg C

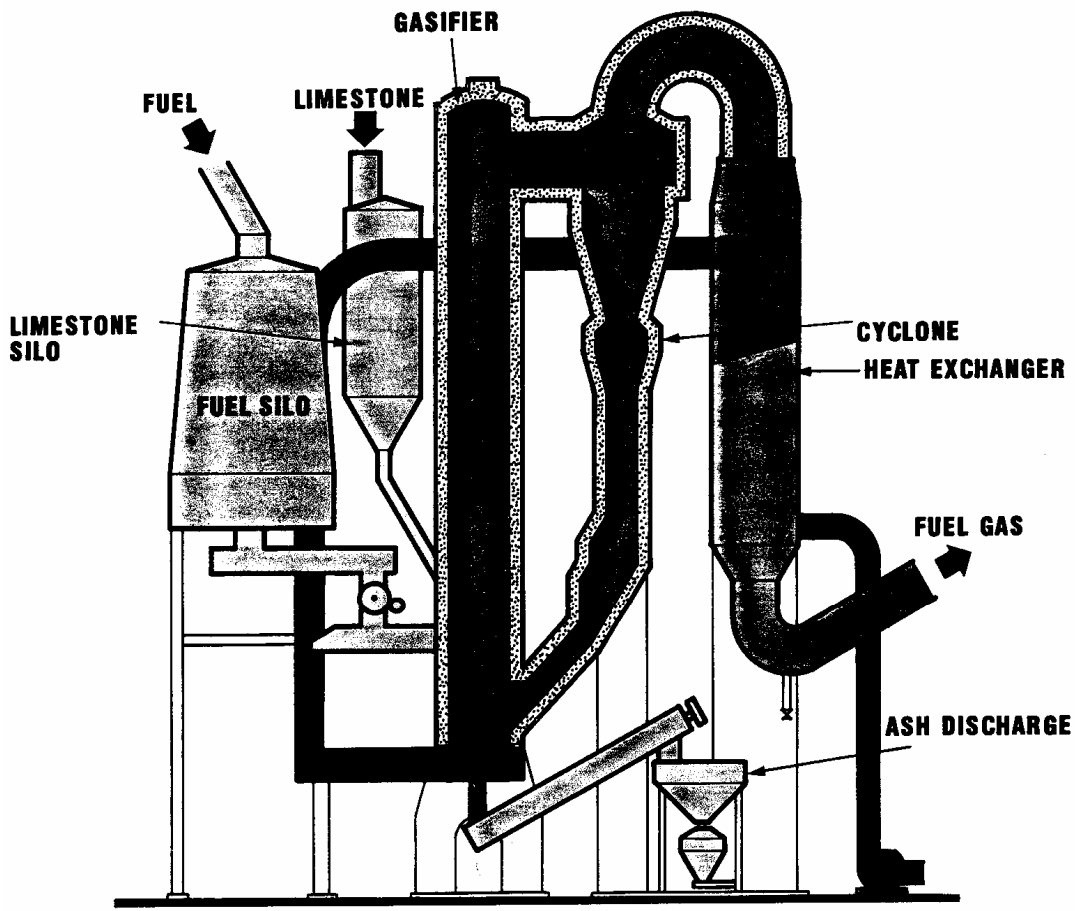
Fuels: coal, peat, wood

# MANY DIFFERENT BOILERS WERE BUILT

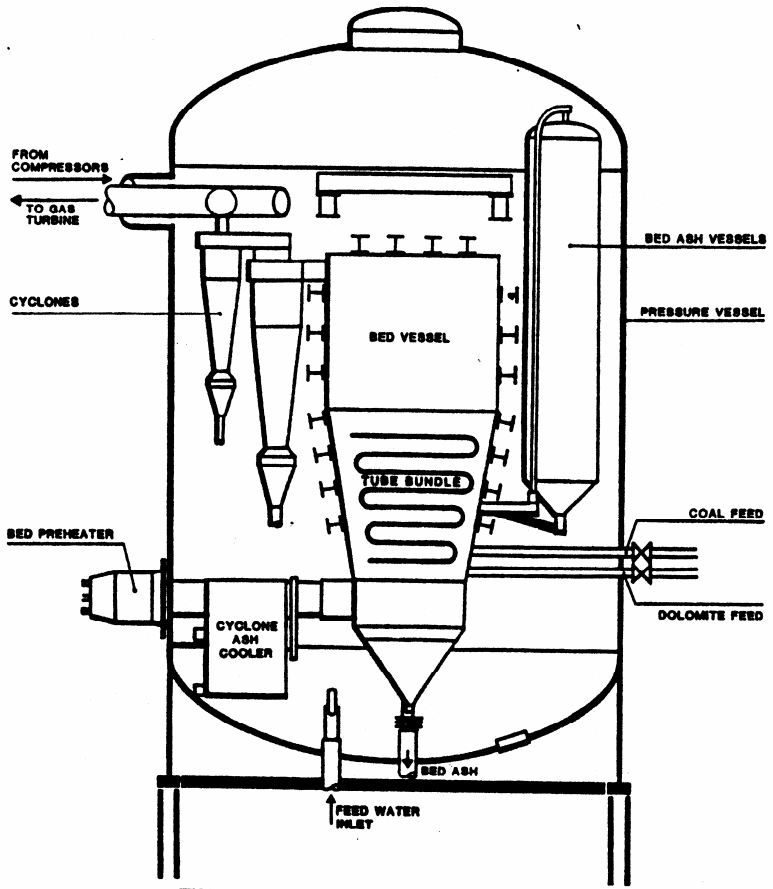


# Gasifier for biofuels built by Götaverken.

## mid 1980's and still in operation!



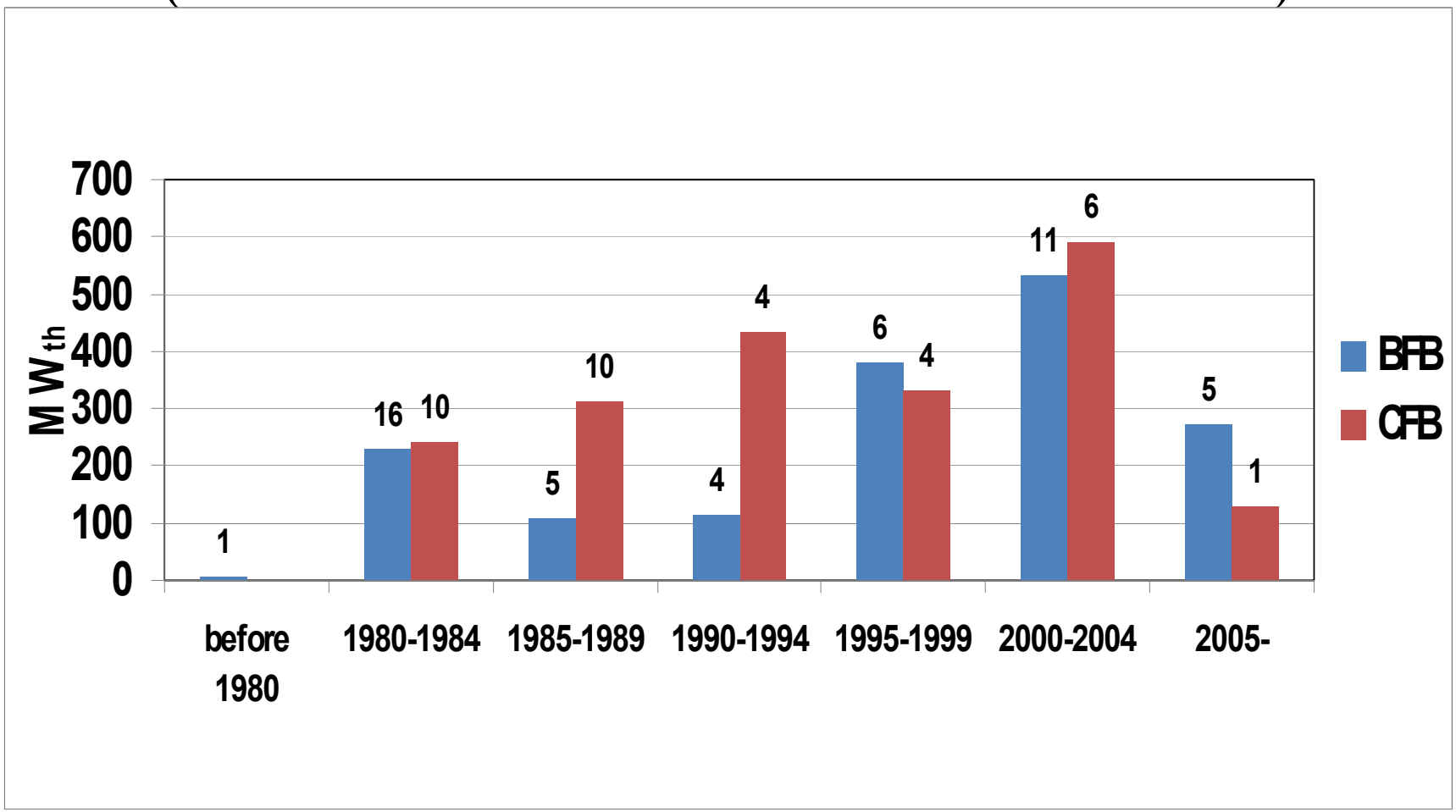
# PFBC (ABB-PFBC)
# Three demo units were built



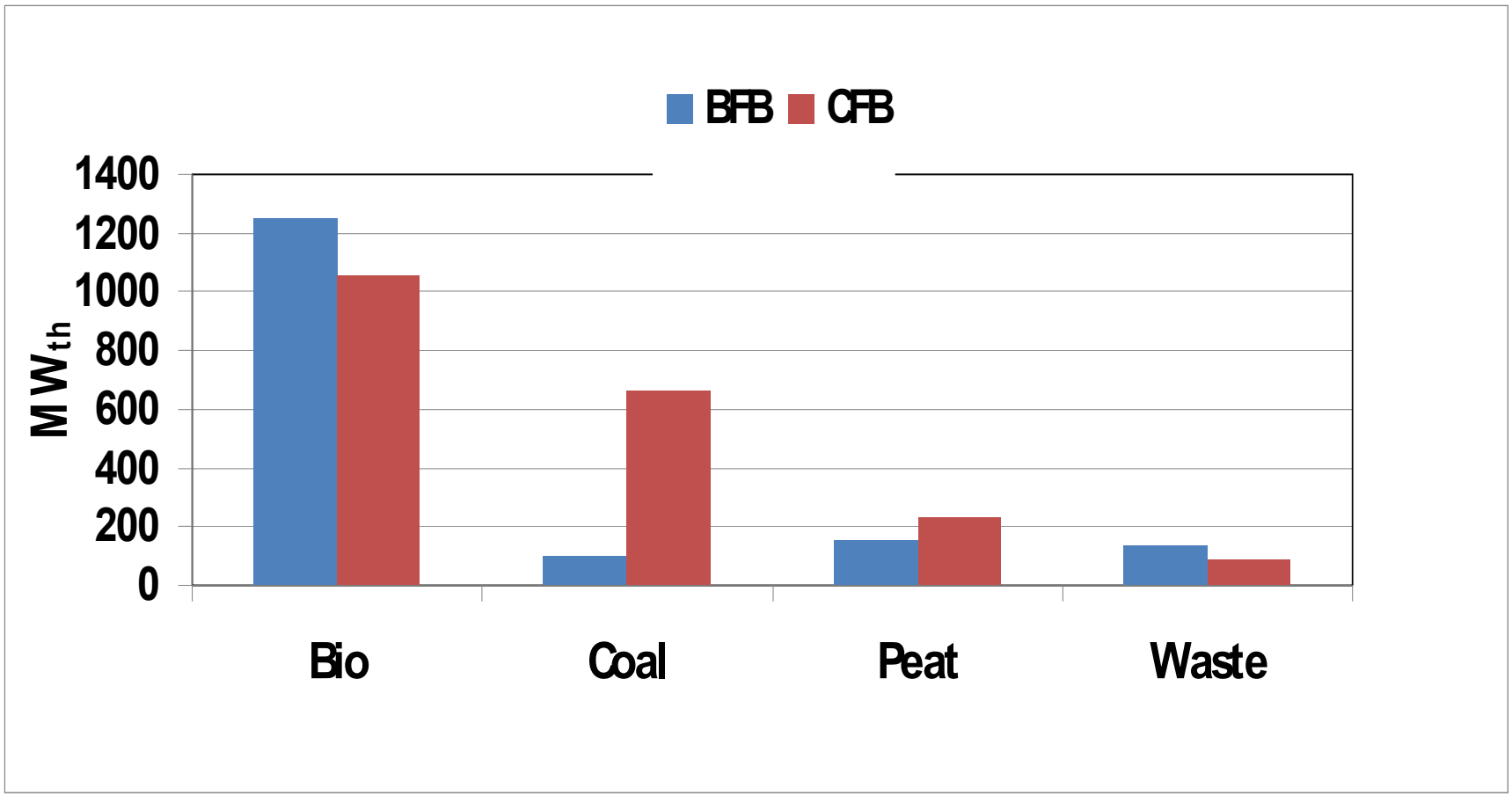
# INTRODUTION OF FB BOILERS IN SWEDEN

$MW_{th}$

(the number of boilers is shown on each bar)



# THERMAL POWER OF BOILERS IN SWEDEN BURNING THE FUELS INDICATED.



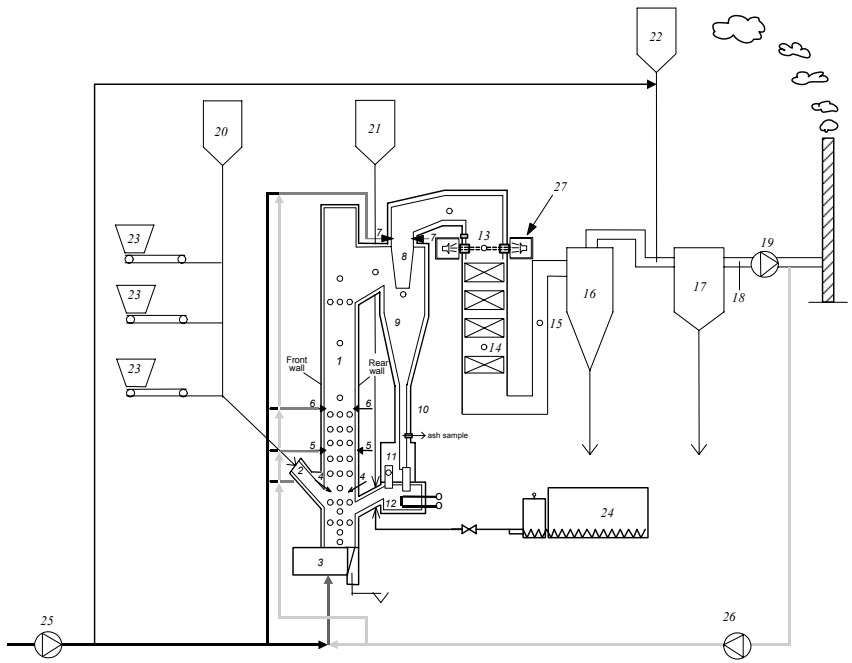
# RESEARCH AND DEVELOPMENT

- Practiaclly oriented work: Värmerforsk
- Academic-scientific-technical work: Chalmers
- Activities at various universities and research institutes: KTH, SP etc.

# DEPARTMENT OF ENERGY & ENVIRONMENT DIVISION OF ENERGY TECHNOLOGY, CHALMERS
## Research groups with relation to combustion

- Prof. A. Lyngfelt---Chemical looping combustion for CO2 reduction
- Prof. F. Johnsson---FBC fluid dynamics and CO2 reduction by oxyfuel combustion
- Assc. Prof. L.-E. Åmand---Emissions from FBC, especially co-combustion & synergy effects
- Assc. Prof. H. Thunman —Interaction reducing-oxidising reactors, at present indirect gasification
- Prof. B. Leckner----Support activities, modelling of gasification

# The Chalmers boiler



# HISTORY OF THE CHALMERS CFB BOILER

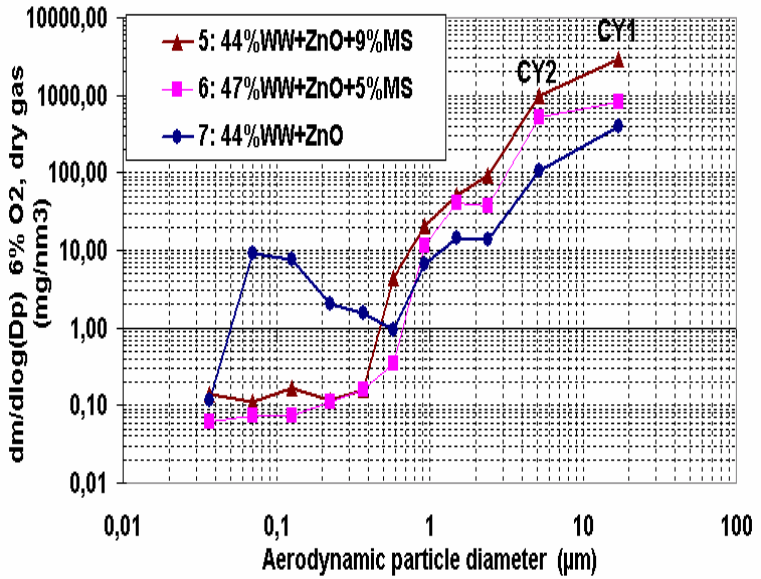
Put into operation 1991, but its operation time is still completely occupied by research!

Research interests in chronological order:

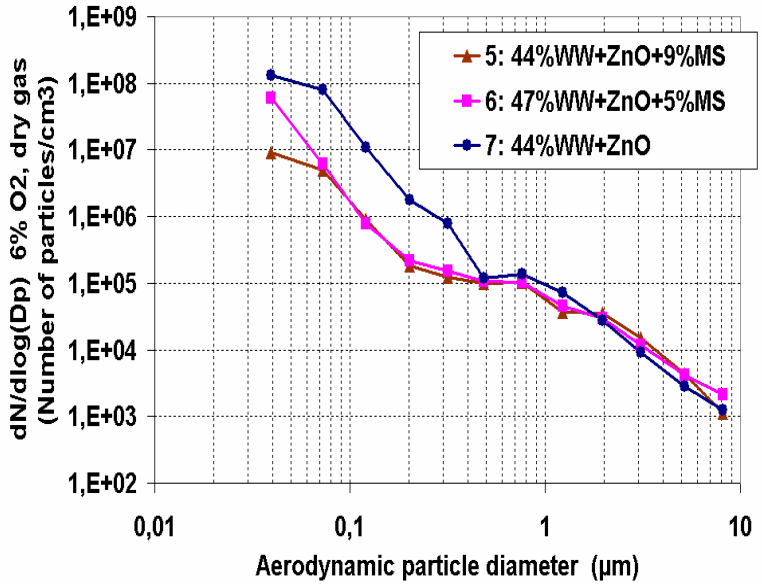
- Fluidization aspects
- Coal combustion and emissions
- Biomass combustion and emissions
- Co-combustion and synergy effects
- Ash behaviour and deposits

# CO-COMBUSTION

## Influence wood-sludge (L.-E. Åmand)

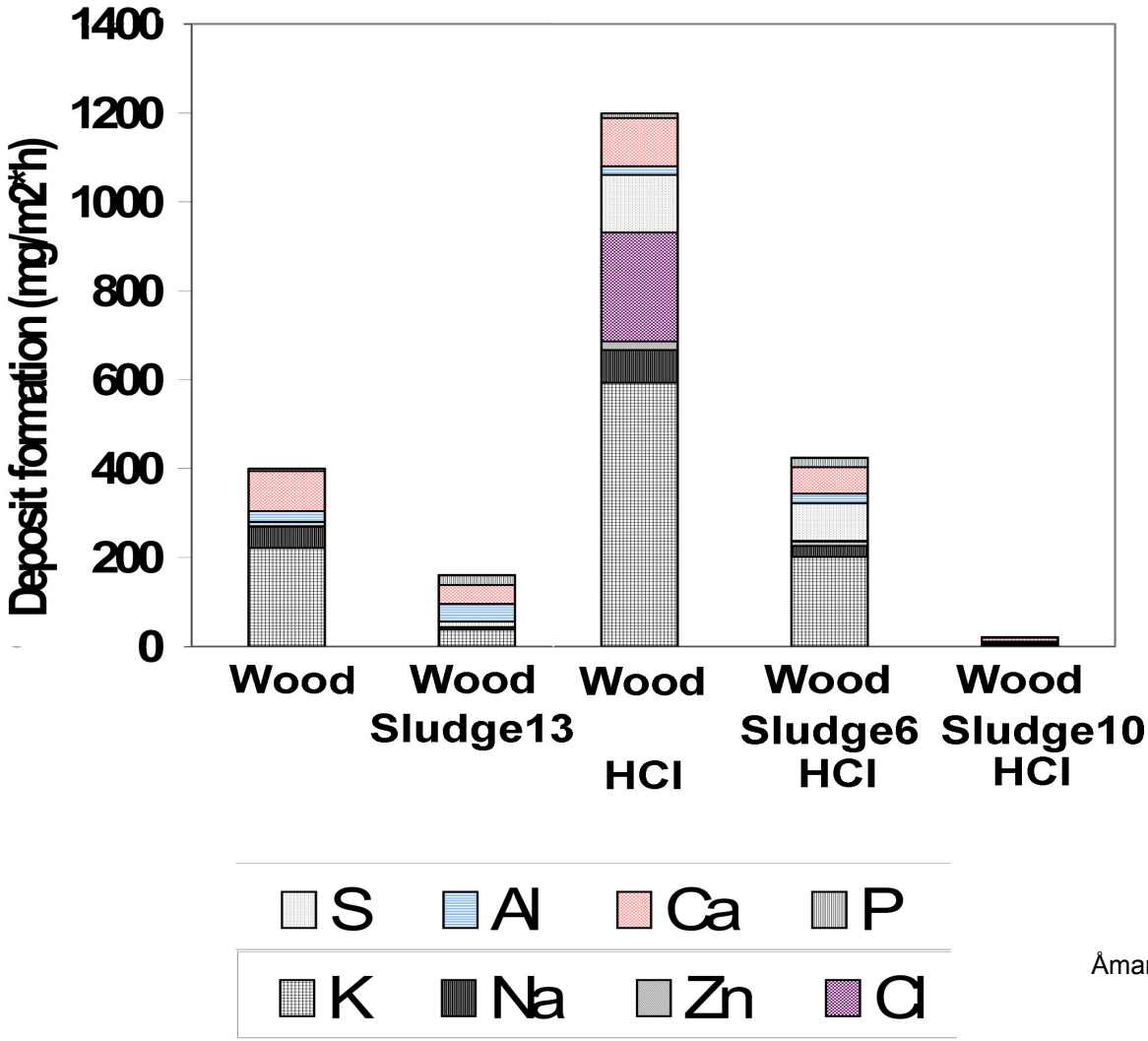



Mass size distribution of particles during wood combustion with and without sludge addition (10%)



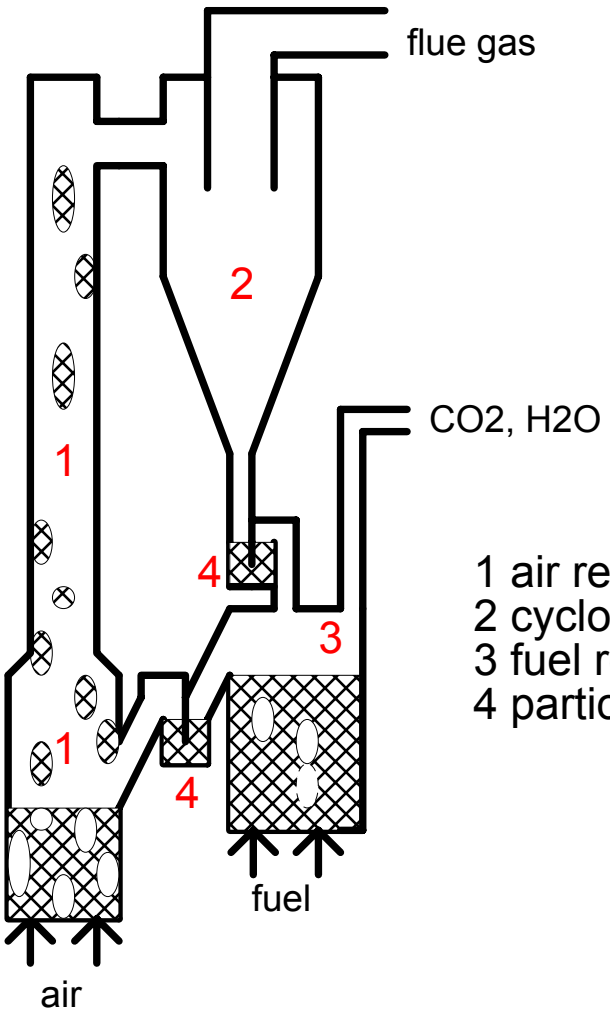

Number size-distribution of particles with and without sludge addition (10%)

# CO-COMBUSTION, INFLUENCE OF CHLORINE AND SLUDGE ON DEPOSITS FROM WOOD




Åmand et al. 2006

# CHEMICAL LOOPING COMBUSTION: 10kW test unit, 2003 (A. Lyngfelt)




1 air reactor, riser
2 cyclone
3 fuel reactor
4 particle locks

**reactor system ↘**

# CHEMICAL LOOPING COMBUSTION

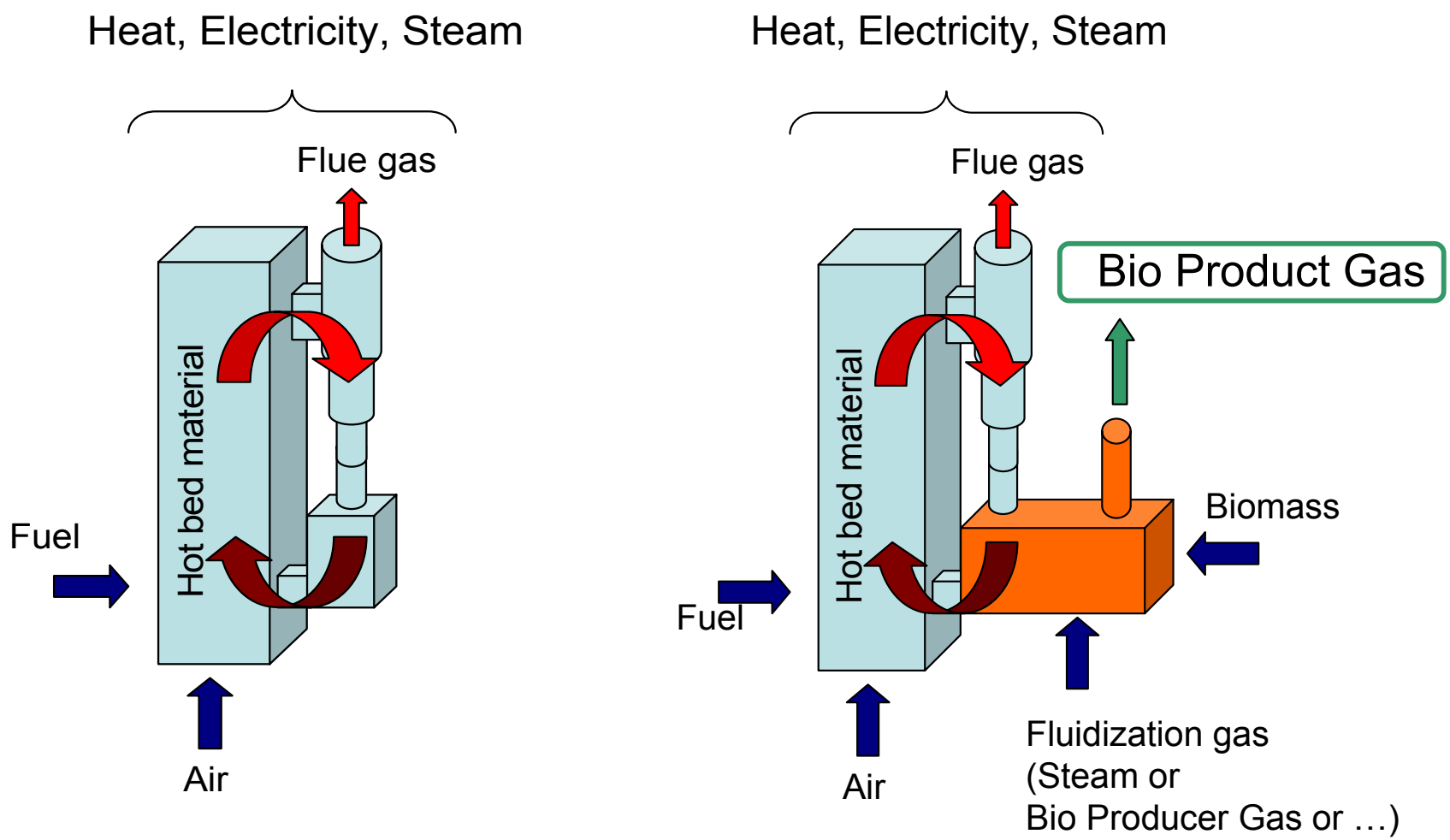
## Goals

- Combustion of gaseous fuels
- Combustion of solid fuels
- Production of $H_2$ from gas with $CO_2$ capture

## Means

- Design of reactor systems
- Investigation of oxygen carriers

# INTEGRATION OF A BIOMASS GASIFIER WITH A CFB BOILER FIRED WITH ANY FUEL (H. Thunman)



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2. Svensson G. and Leckner B., The fluidized bed boiler at Chalmers University of Technology, 7th Int.Conf. on FBC, US Dept. of Energy, DOE/METC/983-48, pp 625-636, 1983.
3. Leckner B., Golriz M.R., Zhang W. and Andersson B.-Å., Boundary layers –first measurements in the 12 MW CFB research plant at Chalmers University, 11th Int. Conf. on FBC, Ed. E.J. Anthony., ASME, New York, pp 771-776, 1991.
4. Strömberg L., Fast FBC of coal, 7th Int. Conf. on FBC, US Dept. of Energy, DOE/METC/983-48, pp1152-1163, 1983.
5. Kullendorff A., Jansson B. and Olofsson J. Förfarande och anordning för styrning av värmeöverföringstalet vid CFB-panna, Patent application 850430 10202 282, 1985.
6. Tellgren E., Two years sucessful operation of the 165 MW th CFB unit in Örebro burning coal, oil, peat and wood waste, 5th Int FBC Combustion Conference, Inst. of Energy, London 1991.
7. H. Thunman, L.-E. Åmand, B. Leckner, F. Johnsson, A cost effective concept for generation of heat, electricity and transport fuel from biomass in fluidized bed boilers – using existing energy infrastructure, Proc.15th European Biomass Conference & Exhibition, Berlin 2007.