STATE OF CFB TECHNOLOGY IN POLAND

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Commercial CFB boilers in Poland

OWNER/LOCATION	YEAR	TYPE	CAPACITY	FUELS
Turow Power Plant S.A.	1998	CFBC Unit 1 and 2 Hot cyclones	2 x 235 MWe	Brown coal, Lignite
Turow Power Plant S.A.	2000	CFBC Unit 3 Hot cyclones	235 MWe	Brown coal, Lignite
Turow Power Plant S.A.	2002-2004	CFBC Units 4, 5 & 6 Hot cyclones	3 x 260 MWe	Brown coal, Lignite
EC Katowice S.A.	2000	CFBC Steam-cooled cyclone	120 MWe	Bituminous coal, coal slurry
Power Plant PSE Jaworzno II S.A.	1999	CFBC Units 1 & 2 Compact CFB	2 x 70 MWe	Bituminous coal, coal slurry
EC Chorzow Elcho	2003	CFBC Units 1 & 2 Compact CFB	2 x 113 MWe	Bituminous coal
EC Zeran, Warsaw	1997	CFBC Unit A Hot cyclones	315 MWe	Bituminous coal
EC Zeran, Warsaw	2001	CFBC Unit B Steam-cooled cyclone	315 MWe	Bituminous coal
EC Bielsko-Biala	1997	CFBC Hot cyclones	177/165 MWe	Bituminous coal
Polpharma Starogard Gdański	1993	CFBC Hot cyclones	2 x 60.2 MWe	Bituminous coal
EC Tychy	1999	CFBC Cymic Internal cyclone	37 MWth electricity 70 MWth dictric heat	Bituminous coal
EC Ostroleka	1997	BFBC bubbling type	30 MWth	Bark, paper waste
EC Siersza	2001, 2003	CFBC Units 1 & 2 Hot cyclones	2 x 338.5 MWth	Bituminous coal

Foster Wheeler references in Poland

EC Gorzóaw S.A.
Gorzów Wielkopolski
HRSG, 514,300 m^{3}n/h, 112 MW$_{th}$
commissioned in: 1997

KGHM Polska Miedz S.A.
Giogów
WHB, 95,000 m^{3}n/h
commissioned in: 1975

Elektrownia Ostroíęka S.A.
Ostroieka
BFB, 35 MW$_{th}$, 47 t/h
commissioned in: 1997

Elektrownia Turów S.A.
Bogatynia
CFB, 2x520 MW$_{th}$, 2x666/596 t/h
commissioned in: 1998

Elektrownia Turów S.A.
Bogatynia
CFB, 520 MW$_{th}$, 666/596 t/h
commissioned in: 2000

Elektrownia Turów S.A.
Bogatynia
CFB, 3x557 MW$_{th}$, 3x704/652 t/h
commissioning: 2002-2004

EC Chorzów Elcho Sp. z o.o.
Chorzów
CFB, 2x274 MW$_{th}$, 2x404 t/h
commissioned in: 2003

PKE S.A. EC Katowice
Katowice
CFB, 352 MW$_{th}$, 483 t/h
commissioned in: 1999

PKE S.A. Elektrownia Łagisza
Bedzin
Supercritical CFB, 966 MW$_{th}$,
1295/1108 t/h
commissioning: 2006

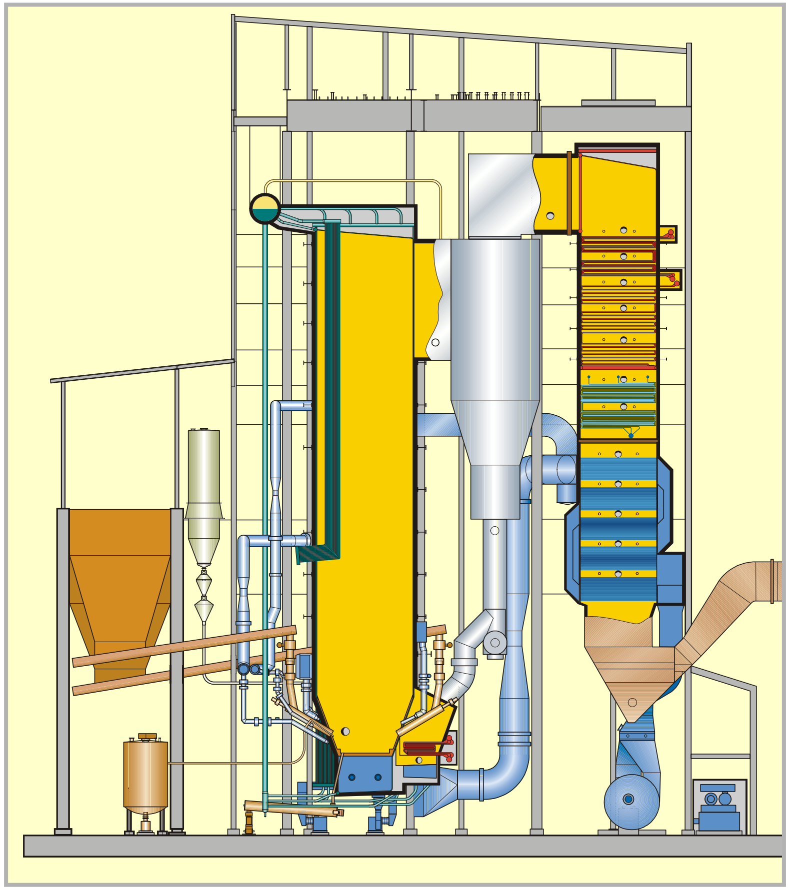
PKE S.A. Elektrownia Jaworzno III
Jaworzno
CFB, 2x180 MW$_{th}$, 2x260 t/h
commissioned in: 1999

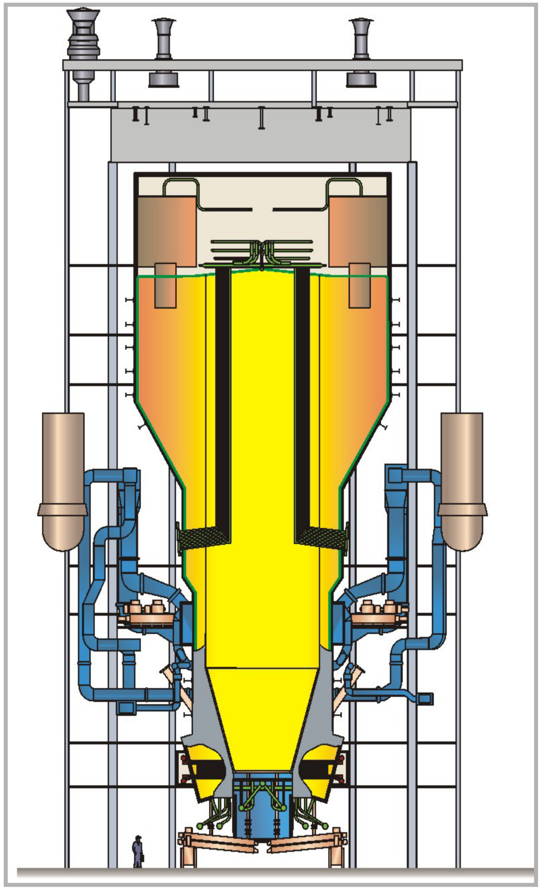
Since 1995 in Poland:

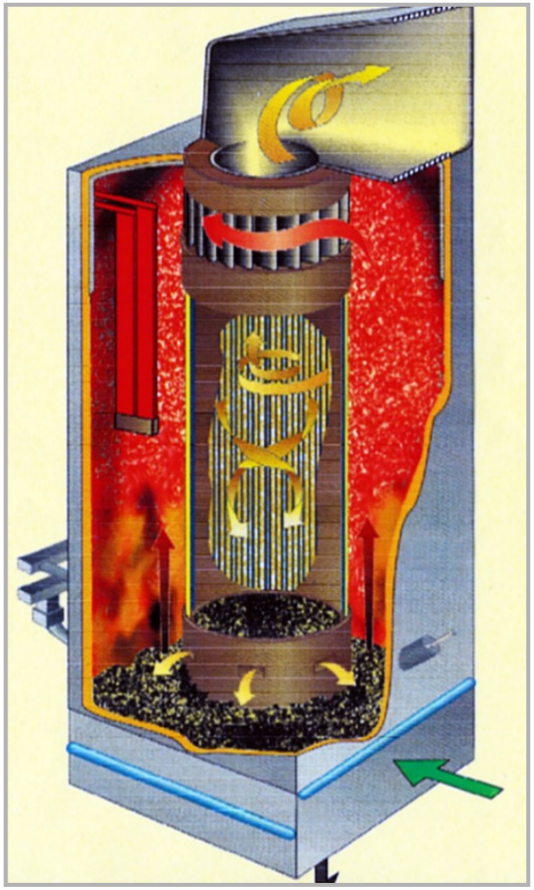
Power from CFB - 2700 MW$_e$

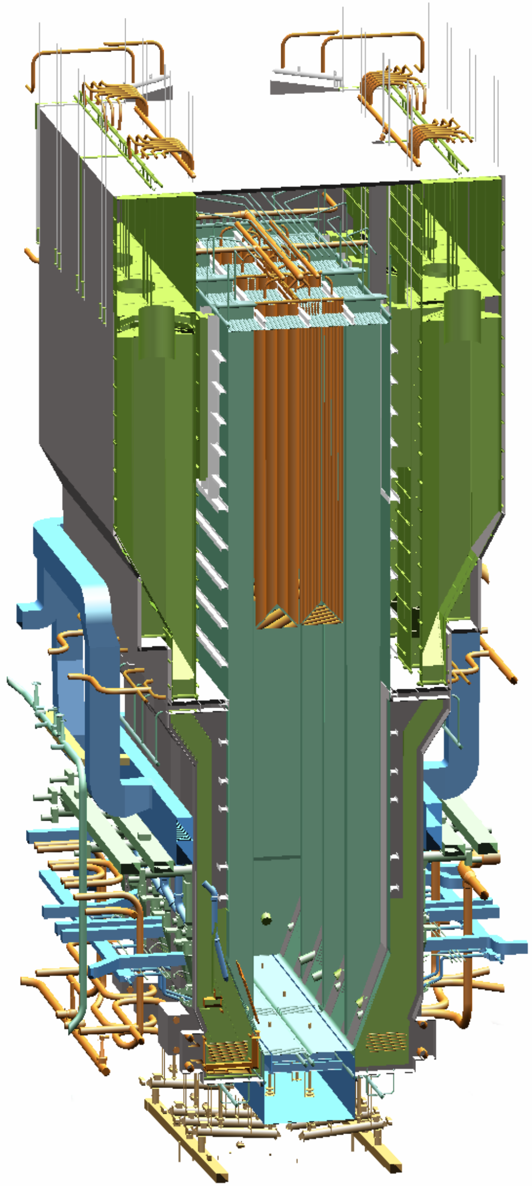
FOSTER WHEELER- 2000 MW$_e$

Types of CFB boilers in Poland









LAGISZA
OTU Supercritical CFB
460 MW_e

Steam Data:
361/306 kg/s, 275/50 bar, 565/580°C

Fuel:
- **Local Bituminous coal from 10 coal mines**
- **Coal Slurry**
- **Biomass**

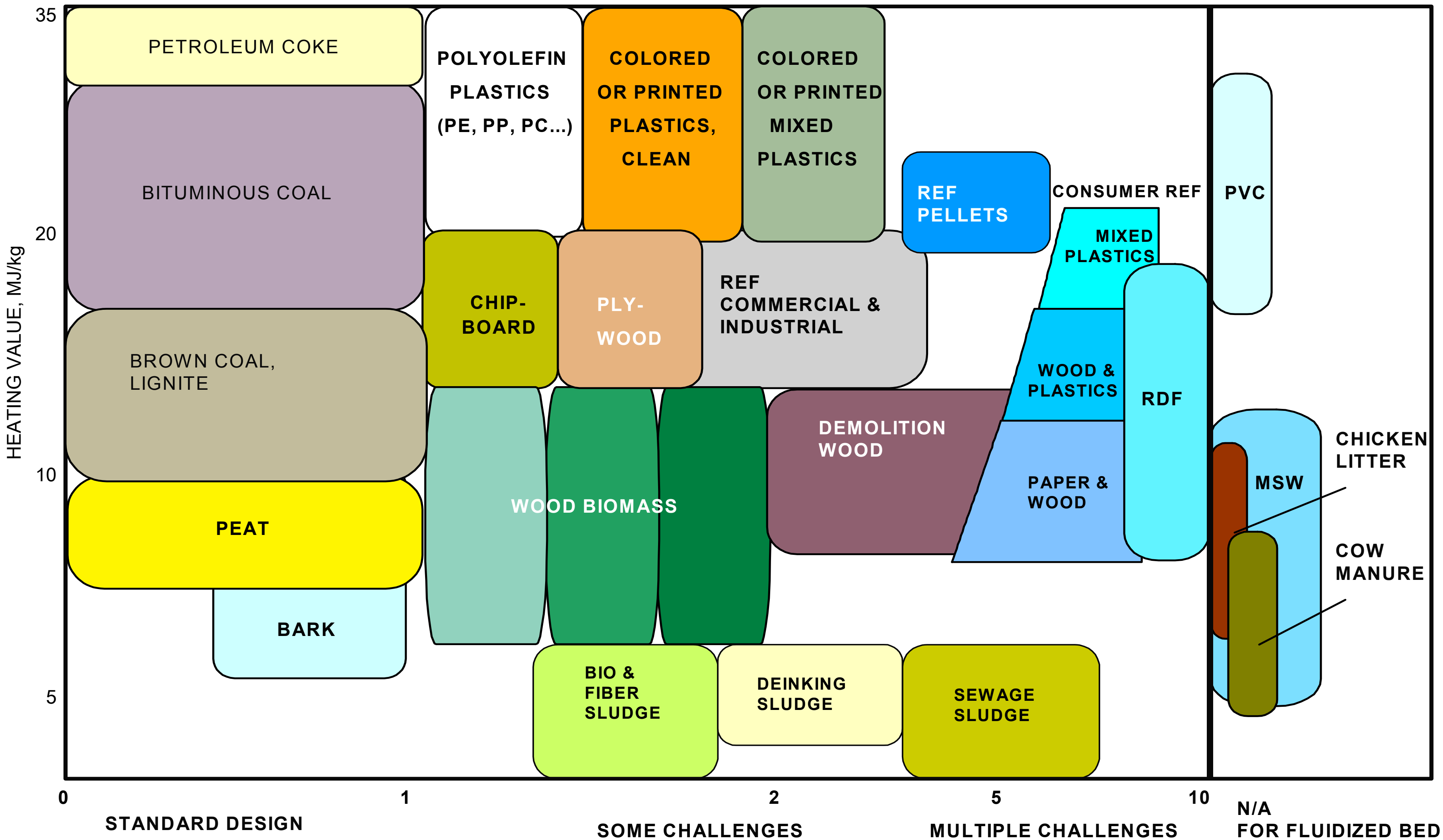
Emissions according to EU's LCP directive achieved without DeNOx and DeSOx plants:

• SO_2	mg/Nm^3	200
• NO_x (as NO_2)	mg/Nm^3	200
• CO	mg/Nm^3	200
• Dust	mg/Nm^3	30

Dry 6 % O_2 content

CFB Fuel Flexibility & Coals

Fluidized Bed Characterization of Solid Fuels



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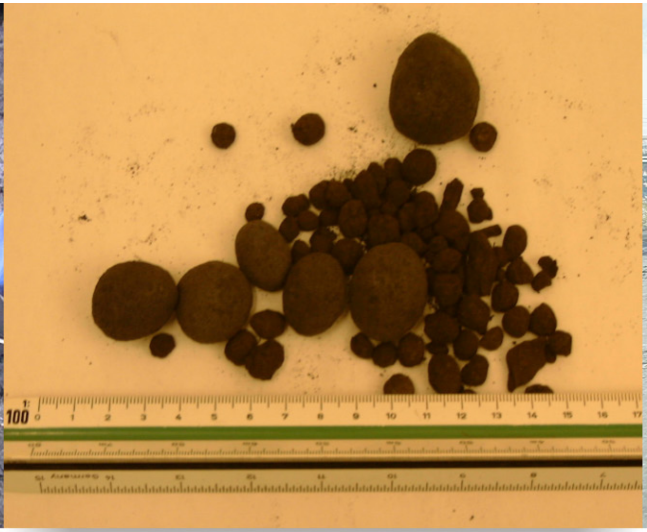
Additional fuels for CFB

Wet Slurry (up to 30%)



Slurry Granulates (up to 50%)

Biomass (up to 10%)

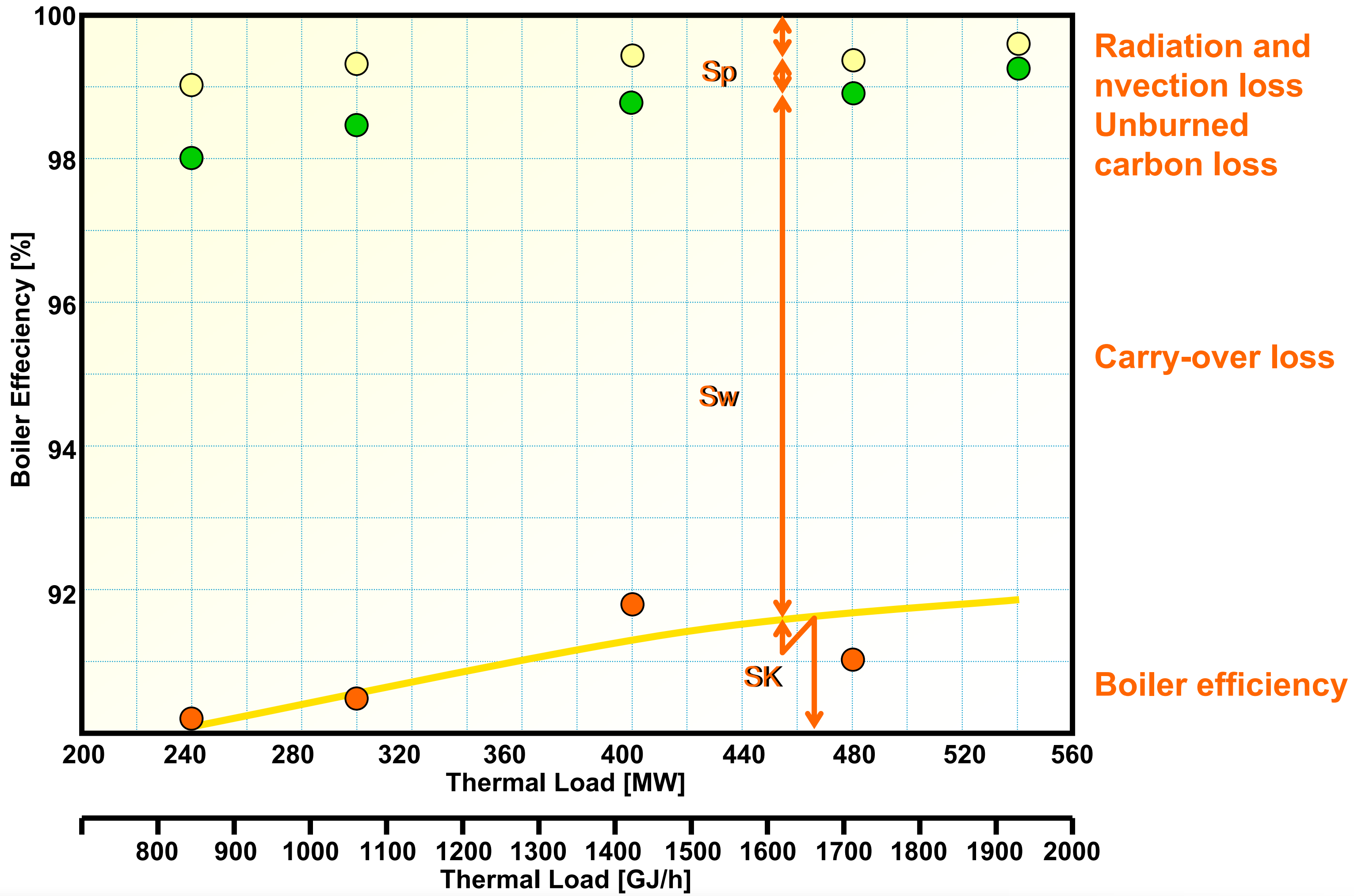
Multifuel Combustion & Utilization of Coal Reject Polish Bituminous Coal & Coal Slurry (max. 50% of Heat)

Jaworzno, Poland: 2 x 180 MW_e, 72.2 kg/s, 138 bar, 540^{O}C

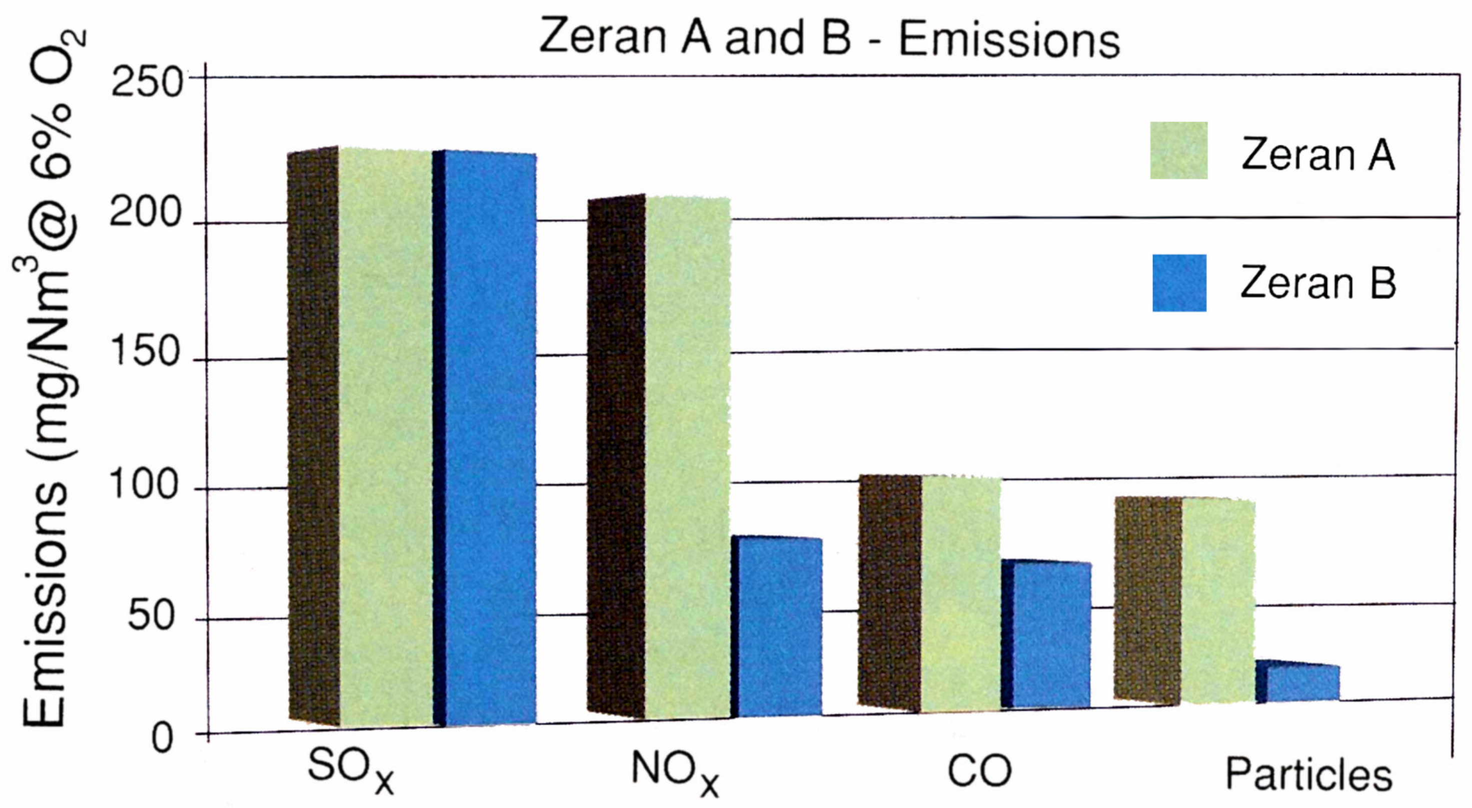
Jaworzno CFB Poland	Coal slurry
Moisture, %	25 – 30
Ash, % dry	40 – 53
Sulfur, % dry	0.9 – 1.4
Volatiles % daf	35 – 40
LHV as fired, MJ/kg	8 – 12

Coal slurry at storage yard

CFB boiler efficiency 235 MW$_e$ CFB, Turow, Poland



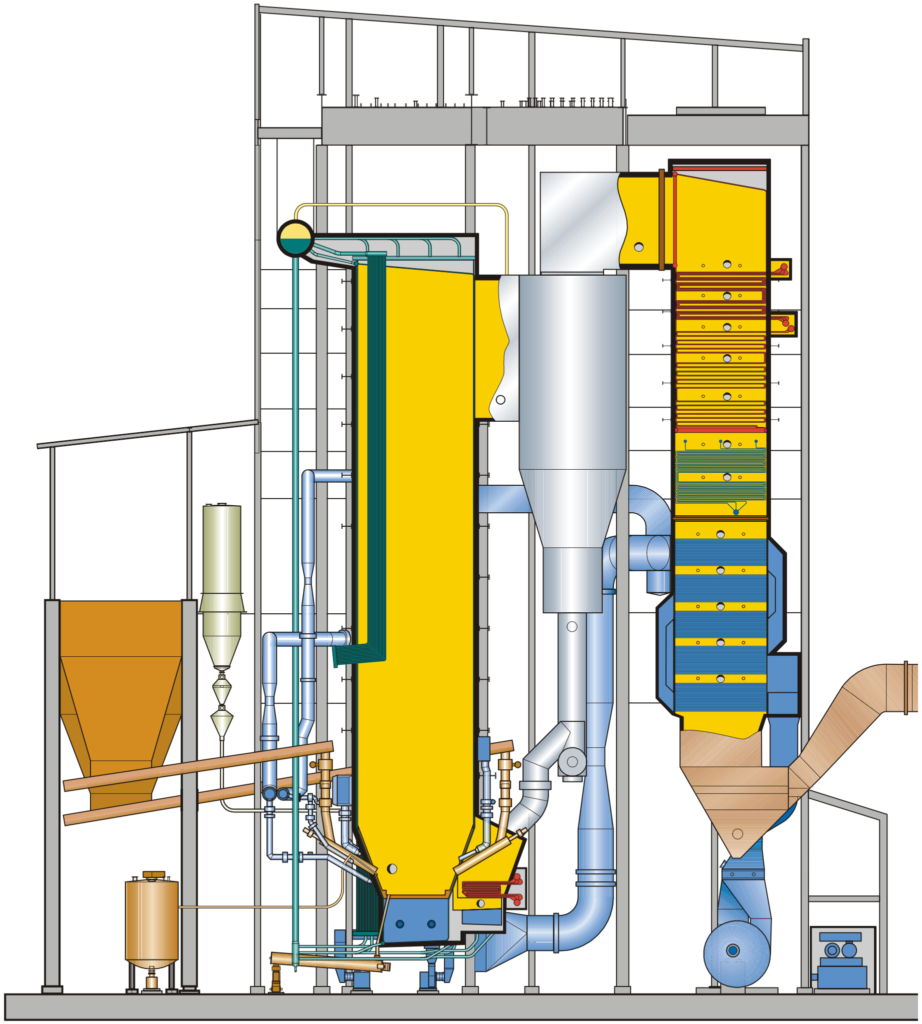
Emissions from 450 t/h CFB Zeran, Poland hard coal 18-24 MJ/kg



Utility CFB, Elcho, Poland 2 x 113 MW_e

Bituminous Coal (S=1.2%, Ash=24%, HHV=23 MJ/kg all in ds.)

	Emissions in 6%-dry O_2	Guaranteed	Measured
Load	**%**	**100**	**100**
NO_x (NO_2)	**mg/Nm^3**	**246**	**111**
SO_2	**mg/Nm^3**	**383**	**327**
Ca/S-ratio	**mol/mol**	**~4**	**1.55**
SO_2-retention	**%**	**-**	**91.3**
CO	**mg/Nm^3**	**200**	**29**
Dust	**mg/Nm^3**	**50**	**< 17**

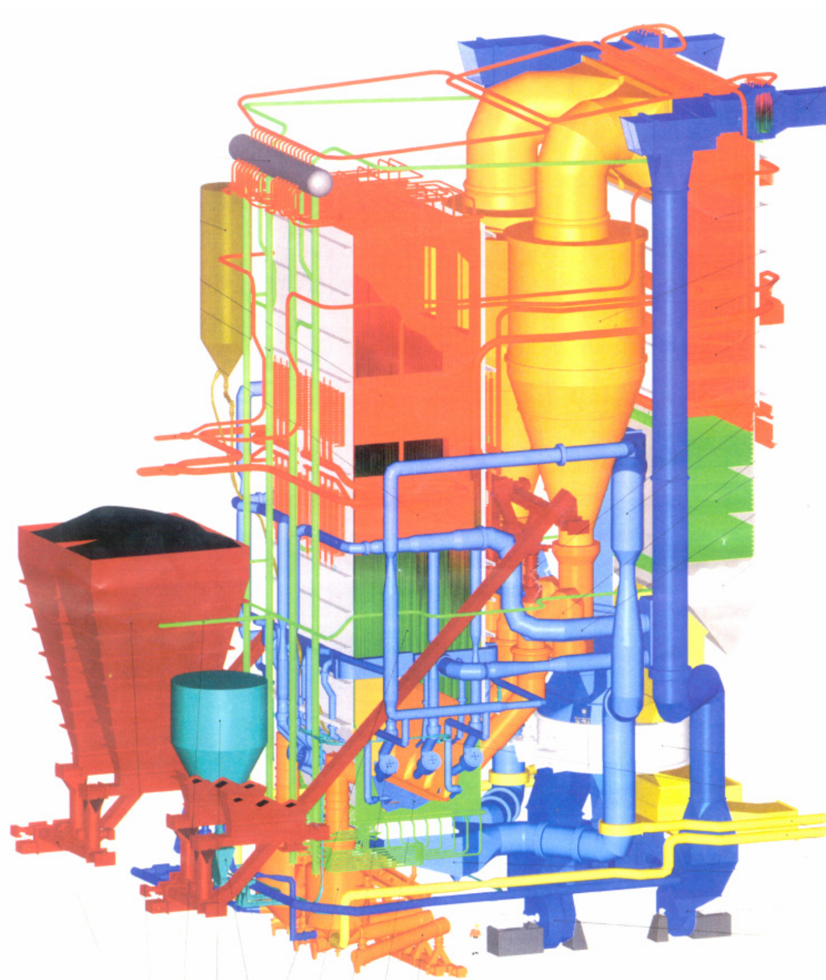


Katowice, Poland BCF-100

352 MW_t, 134 kg/s, 139 bar, 540^oC

Emissions in 6%-dry O_2	Guaranteed mg/Nm^3	Measured mg/Nm^3
SO_2	540	417
NO_x (NO_2)	460	155
CO	200	52
Dust	50	8,3

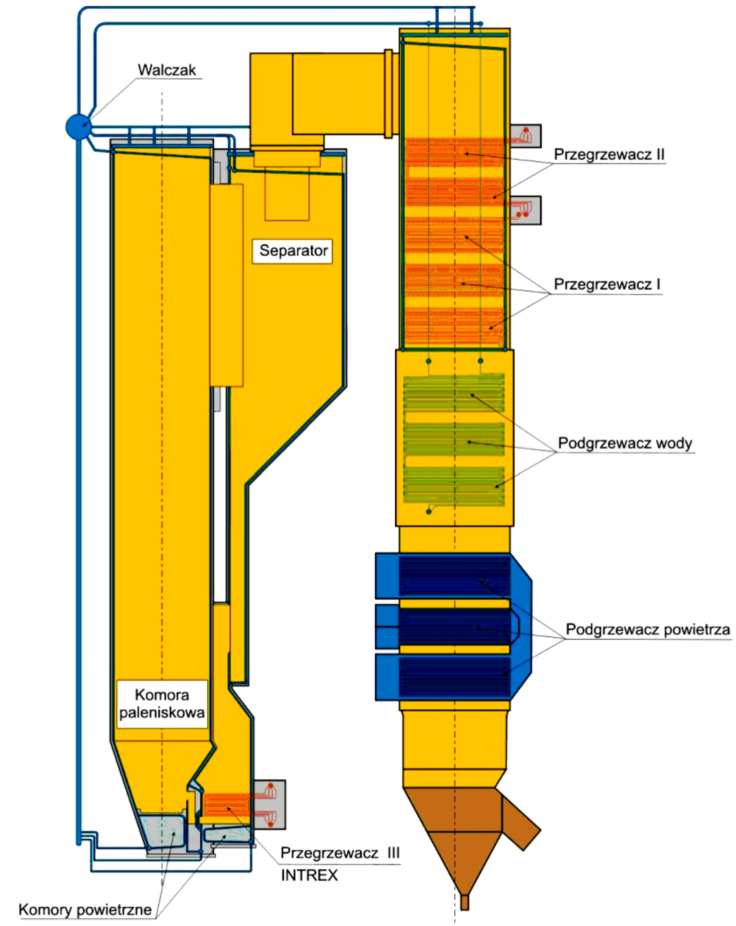
Siersza PKE SA, Poland
OFz-425



	Parameter	Unit	Guaran-teed	Measured
1	Rated steam output	t/h	425	(447) 425
2	Steam - temperature - pressure	°C MPa	560 16,0	560 16,0
3	Flue gas temeprature	°C	135	130,8
4	Efficiency	%	≤ 91,0	92,16
5	Molar ratio Ca/S	mol/mol	3,15	1,61
6	$S0_2$ emission	mg/Nm^3	≤ 337,5	293
7	$N0_x$ emission	mg/Nm^3	≤ 307,8	167
8	Dust	mg/Nm^3	≤ 51	22,8

Jaworzno, Poland

2x180 MW, 72.2 kg/s, 138 bar, 540^{0}C

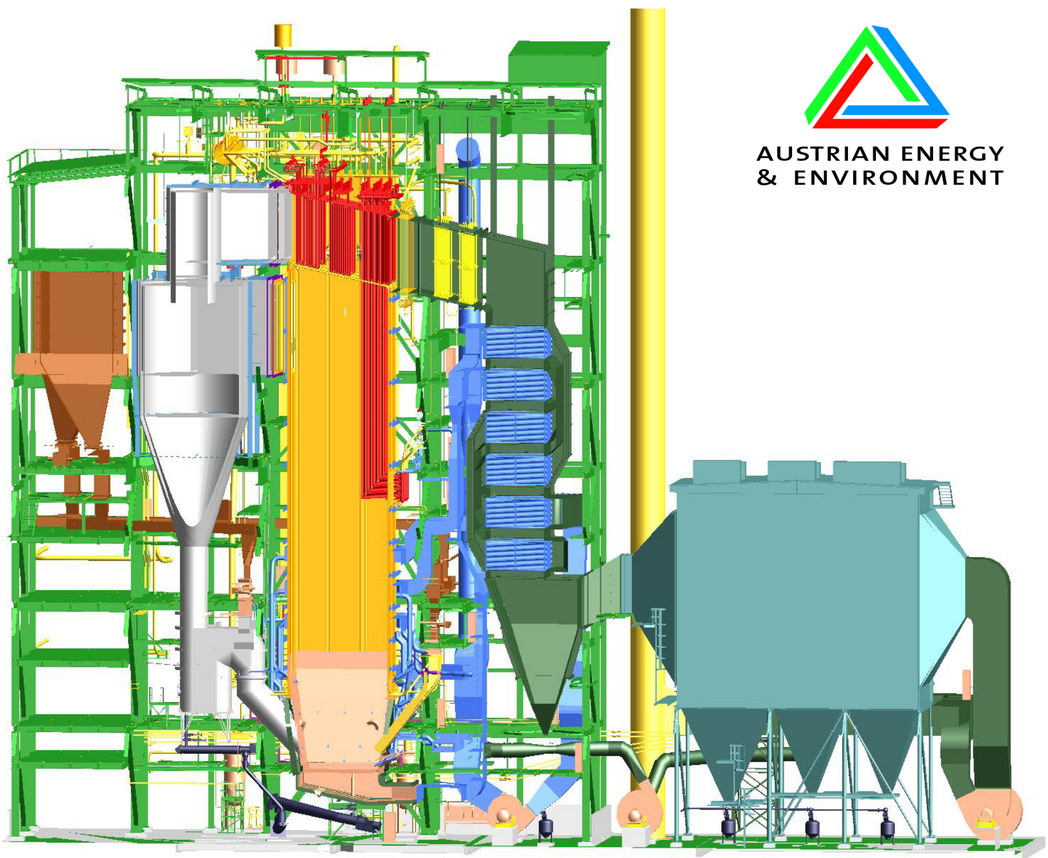


Thermal capacity	180 MW_t
Electrical output	70 MW_e
Live steam pressure	13.7 MPa
Live steam temperature	540^{0}C
Rated steam output	260 t/h
Feed water temperature	220^{0}C
Efficiency	91%
Emissions	
NO_2	470 mg/Nm^3
SO_2	560 mg/Nm^3
CO	310 mg/Nm^3
Pył	50 mg/Nm^3

Design fuel parameters

Coal		Coal slurry	
LHV	17000 – 20000 kJ/kg	LHV	8000 - 12000 kJ/kg
ash contents	15 – 25 %	ash contents	30 - 37 %
moisture contents	15 –20 %	moisture contents	30 - 35 %
sulphur contents	0.8 –1.5 %	sulphur contents	0.7 –1.0 %

Swiecie, Poland
CFB Boiler



AUSTRIAN ENERGY & ENVIRONMENT

STEAM FLUX
max. 234/180 t/h
min. 117/89 t/h

STEAM PRESSURE AND STEAM TEMEPERATURE
9,6 MPa i 510 °C

EFFICIENCY
92,0/90,8 %

EMISSIONS [mg/Nm³]:
SO_2 < 250,
NO_x < 200 (300),
CO < 100/200,
pył < 50/30

LOAD CHANGE
± 7%/min.

AVAILABILITY
96%

Swiecie, Poland
CFB Boiler

- The boiler was designed to co-combustion of biomass as well as the coal in any proportions, as and the burning the exclusively only biomass and the only coal
- Source of delivery of fuel:
    - biomass (bark and sawdusts) from pulp mill FRANTSCHACH SWIECIE – 1.900.000 GJ/a
    - biomass (bark and sawdusts) from external sources
    - – 300.000 GJ/a

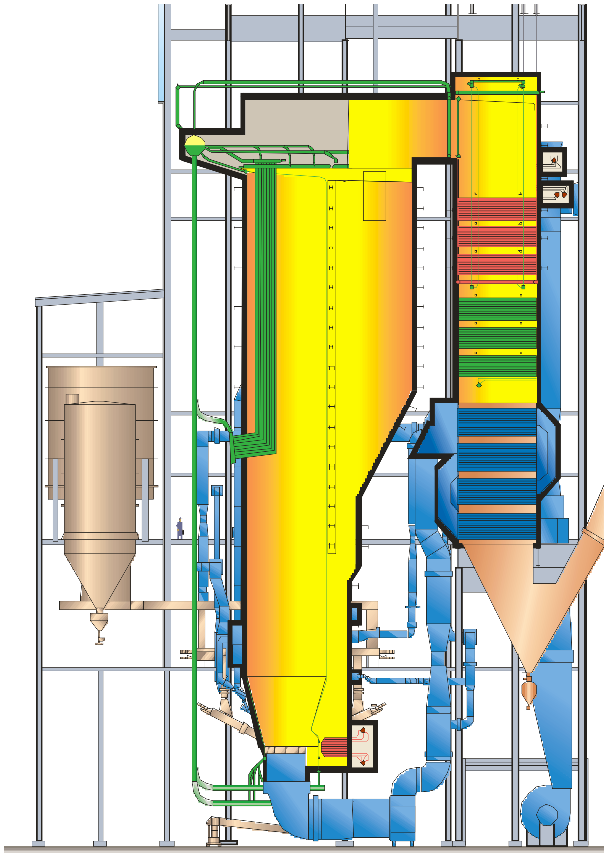
    hard coal – 1.500.000 GJ/a (65.000 t/a)
  - Maximum dimension of chips - 35 x 35 x 75 mm
  - Minimum dimension of chips - 1 mm
  - Maximum content of moisture - 65 %

Plant's Efficiency

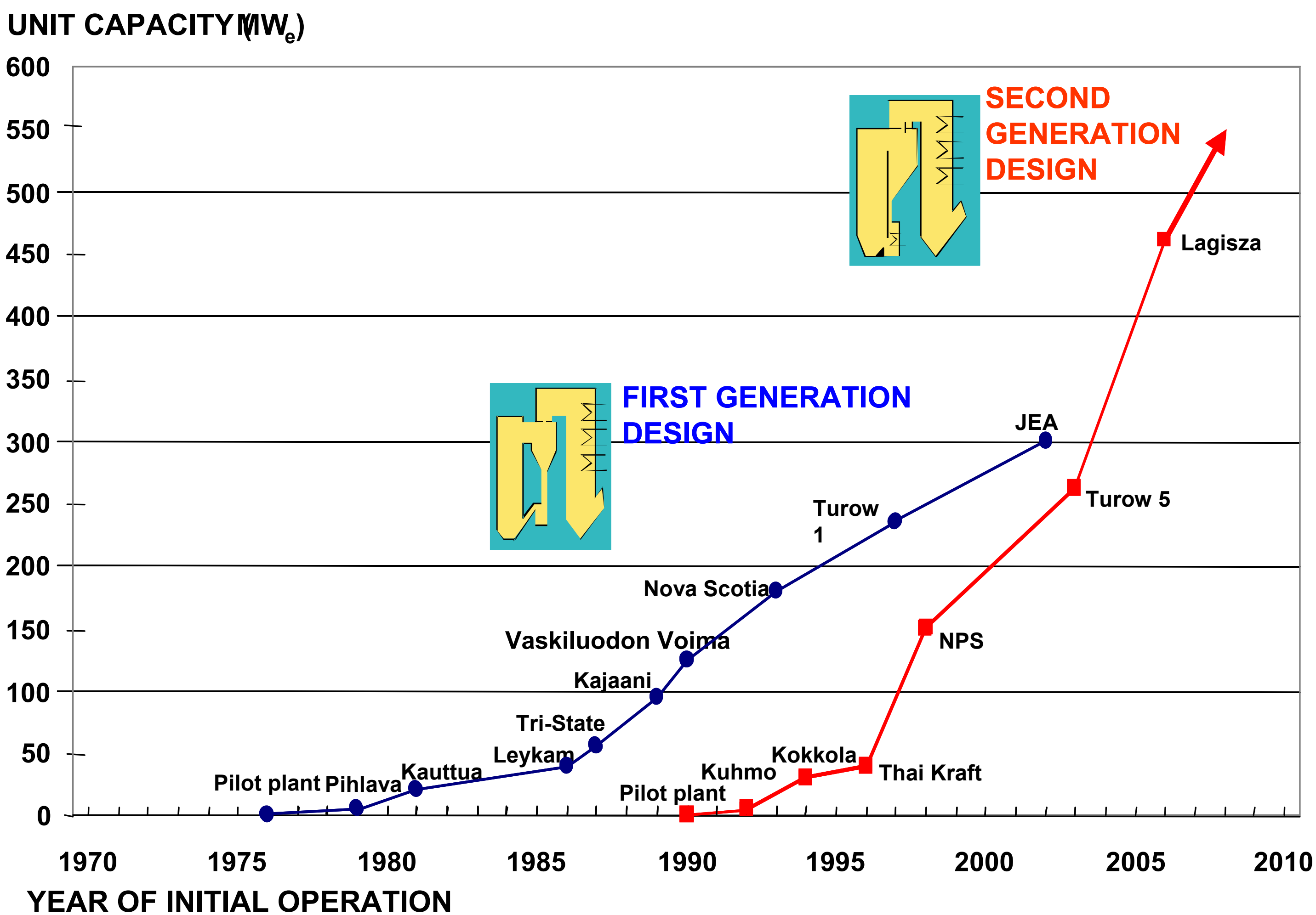
- In case of good quality coals → CFB same as PC
- CFB has multifuel possibility
- In Łagisza (460 MW_e, 361/308 kg/s, 282.6/51.3 bar, 563/582°C)
- Plant's efficiency ~ 43.37 %
- Boiler efficiency ~ 94.83%

CFB Status

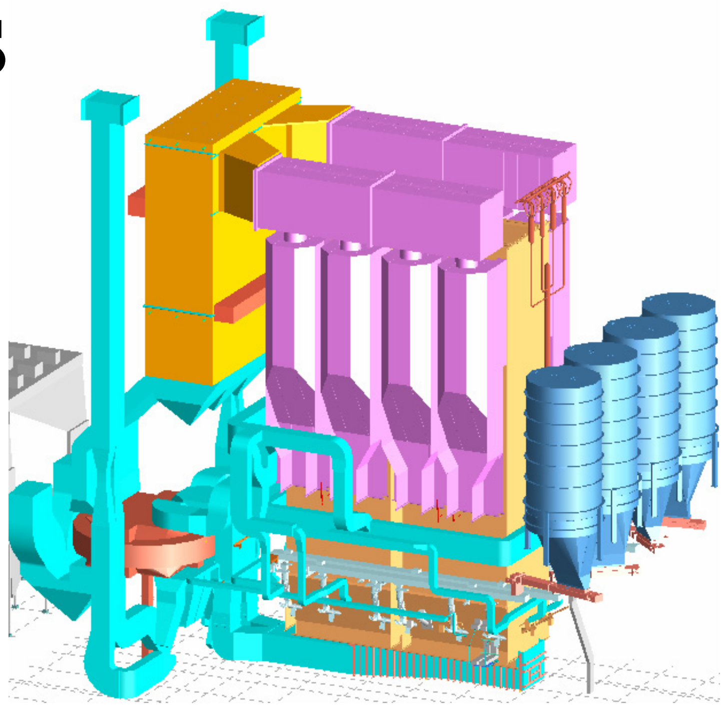
- CFB has established leading position in small and mid-size industrial and utility plants
- Fuel flexibility is a special advantage
  - Wide range for design coals
  - Opportunity fuels (biomass etc)
  - Hard-to-Burn fuels (petcoke etc)
- Excellent emission performance
  - No DeSOx / DeNOx –plants required
- CFB has reached utility scale
  - Sizes up to 300 MW_e in operation
  - 460 MW_e under cunstruction



Scale-Up and Key References



Once-Through CFB Key Design Features



- Proven and Efficient CFB Process
- High Plant Efficiency
  - Supercritical Steam Pressure
  - Sliding Pressure Operation
- BENSON Vertical Tube Technology
  - Vertical Tube Furnace Walls
  - Low Pressure Drop
- Integrated Steam Cooled Solids Separators
  - Minimum amount of refractories
- INTREX™ Fluidized Bed Heat Exchanger
  - High Heat Transfer Rates Minimize Surface Area
- Regenerative Air Heater
  - Maximum Boiler Efficiency

PKE / Łagisza Project

- Customer: Poludniowy Koncern Energetyczny (PKE), Polish Electrical Utility Company
- 460 MWe power plant located in the Łagisza power plant in southern Poland
- Contract awarded December 30, 2002
- Foster Wheeler delivery
  - Boiler island – CFB technology
  - Auxiliary equipment
  - Flue gas heat recovery system
  - Boiler house with foundations

CFB More Economical than PC Alternative

CFB alternative had:

- 20 % lower investment cost than PC with SCR + FGD
- Better net plant efficiency 0.3 %-unit better than with PC
- Potential for savings in fuels costs due to multi-fuel capability

Plant Design Parameters

		Gross/ Net
Electrical Output	MW	460 / 439
Plant efficiency	%	45.3 / 43.3

		SH / RH
Steam flow	kg/s	361 / 306
SH pressure	bar	275 / 55
SH temperature	°C	560 / 580
Feed water temperature	°C	290

Project Schedule

• Contract Signing	December 30, 2002
• Notice to Proceed	January 1, 2006
• Hand Over	March 15, 2009

Fuel Flexibility

		Bituminous Coal		Coal Slurry[1] (< 30 %)
		Design coal	Range	Range
LHV (a.r.)	MJ/kg	20	18 - 23	7 – 17
Moisture	%	12	6 - 23	27 – 45
Ash (a.r.)	%	23	10 - 25	28 – 65
Sulphur (a.r.)	%	1.4	0.6 - 1.4	0.6 – 1.6
Chlorine (dry)	%	< 0.4	< 0.4	< 0.4

Provisions to burn dried coal washery rejects[1] up to 50 % and biomass[1] up to 10 %

[1] Additional fuels

Consumption data

- Design fuel consumption - 50.38 kg/s /181.4 t/h/
- Limestone consumption (for design coal, sulphur 1.2%) - 4.44 kg/s
- Auxiliary power consumption - 14.6 MW

Emission Performance

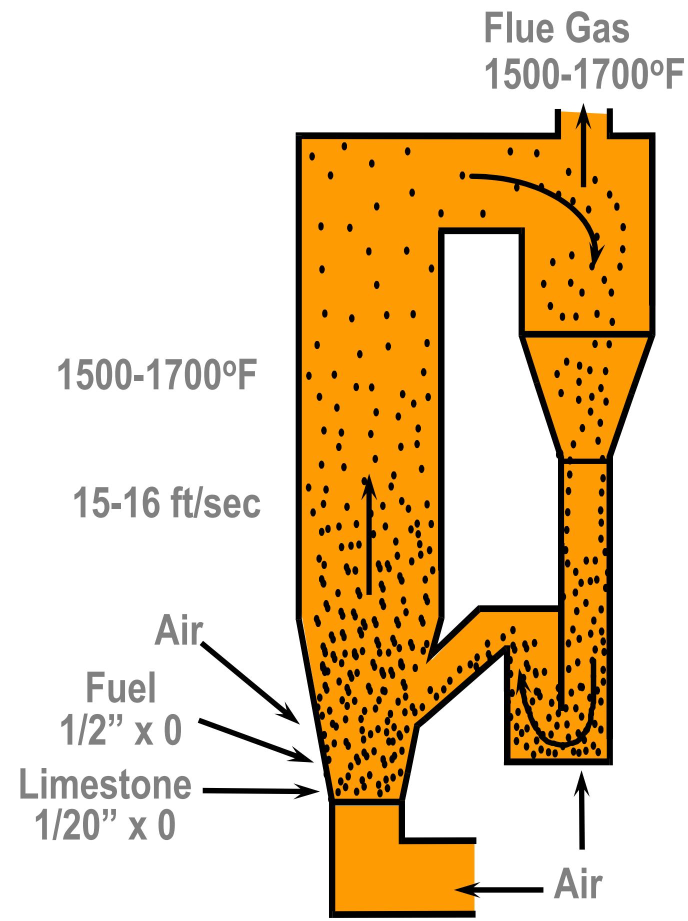
Emissions according to EU's LCP directive achieved without DeNOx and DeSOx plants:

• SO_2	mg/Nm^3	200
• NO_x (as NO_2)	mg/Nm^3	200
• CO	mg/Nm^3	200
• Dust	mg/Nm^3	30

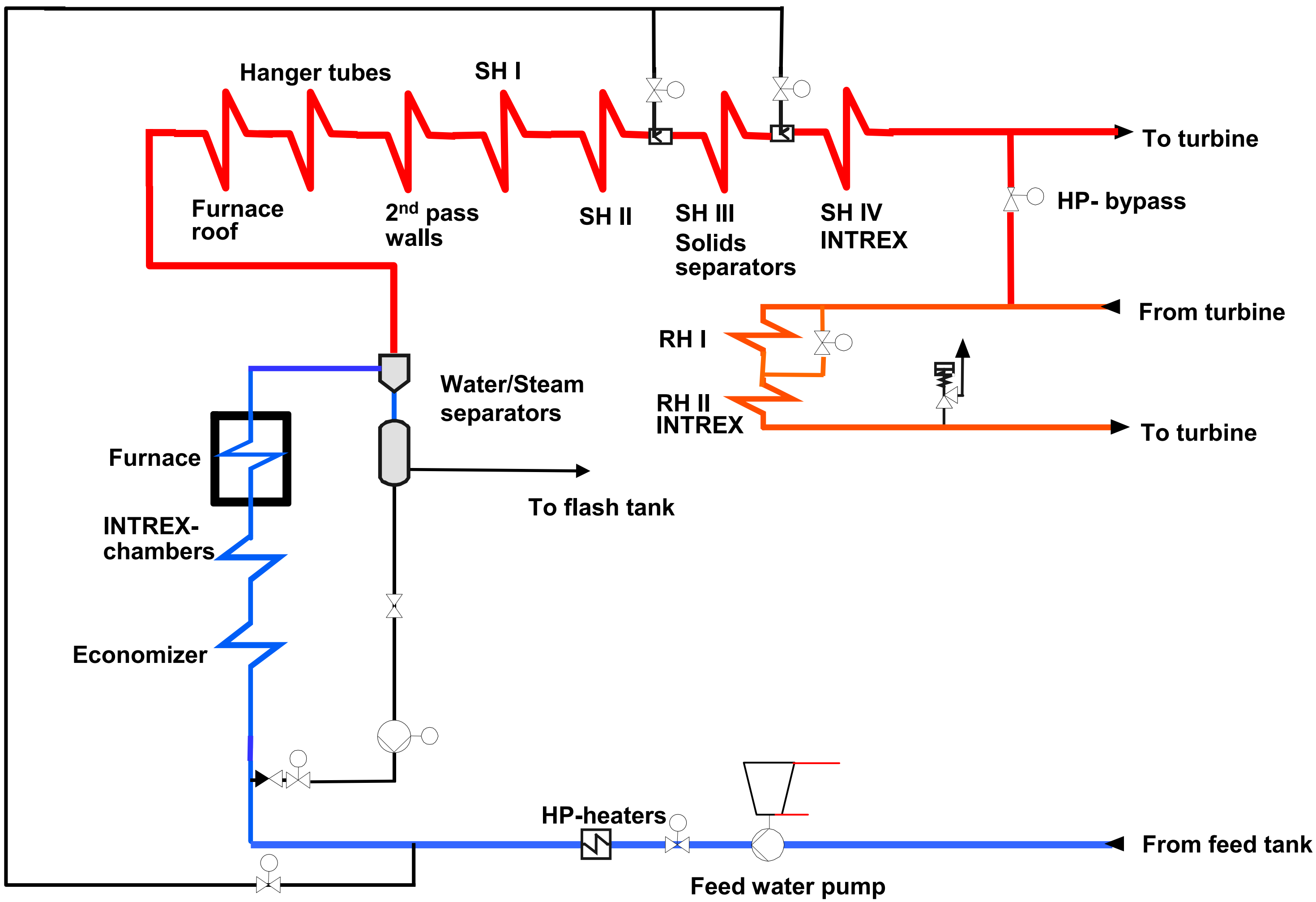
Dry 6 % O_2 content

CFB Process Advantages

Feature	Benefit
Low Furnace Temps.	Low NO_x In Bed SO_2 Capture Fuel Flexibility
Hot Circulating Solids	Tolerant to Fuel Variations Simple Feed Systems Constant Heat Flux Ideal for SNCR
Long Solid Residence Time	Good Fuel Burnout Good Sorbent Utilization

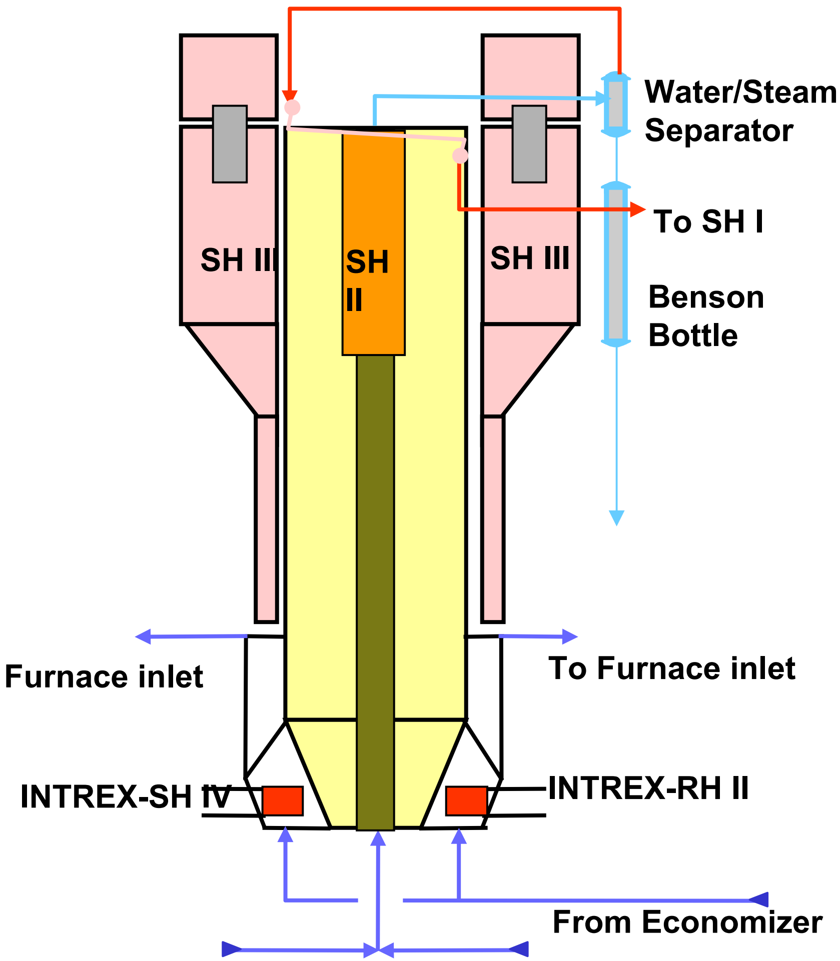


Steam Cycle



Hanger tubes
SH I
Furnace roof
2nd pass walls
SH II
SH III
Solids separators
SH IV
INTREX
To turbine
HP- bypass
From turbine
RH I
RH II
INTREX
To turbine
Water/Steam separators
To flash tank
Furnace
INTREX-chambers
Economizer
HP-heaters
Feed water pump
From feed tank

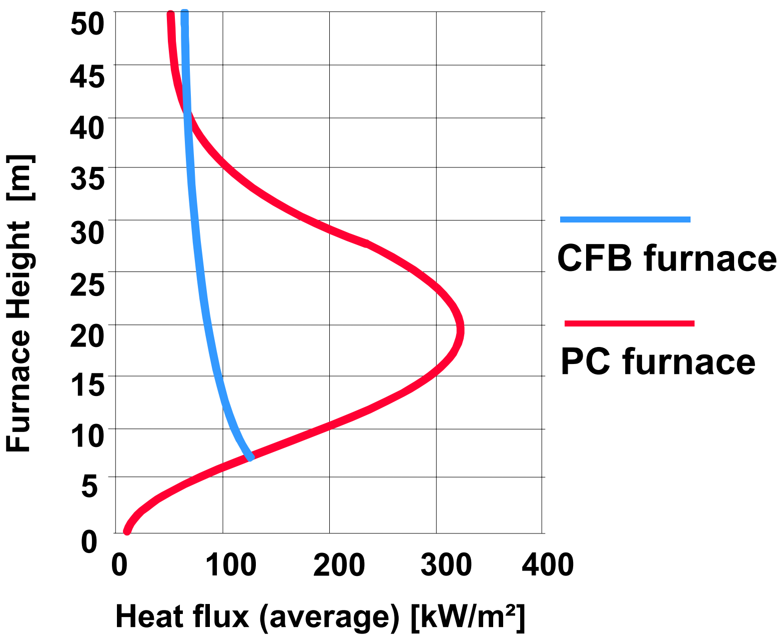
Furnace Design

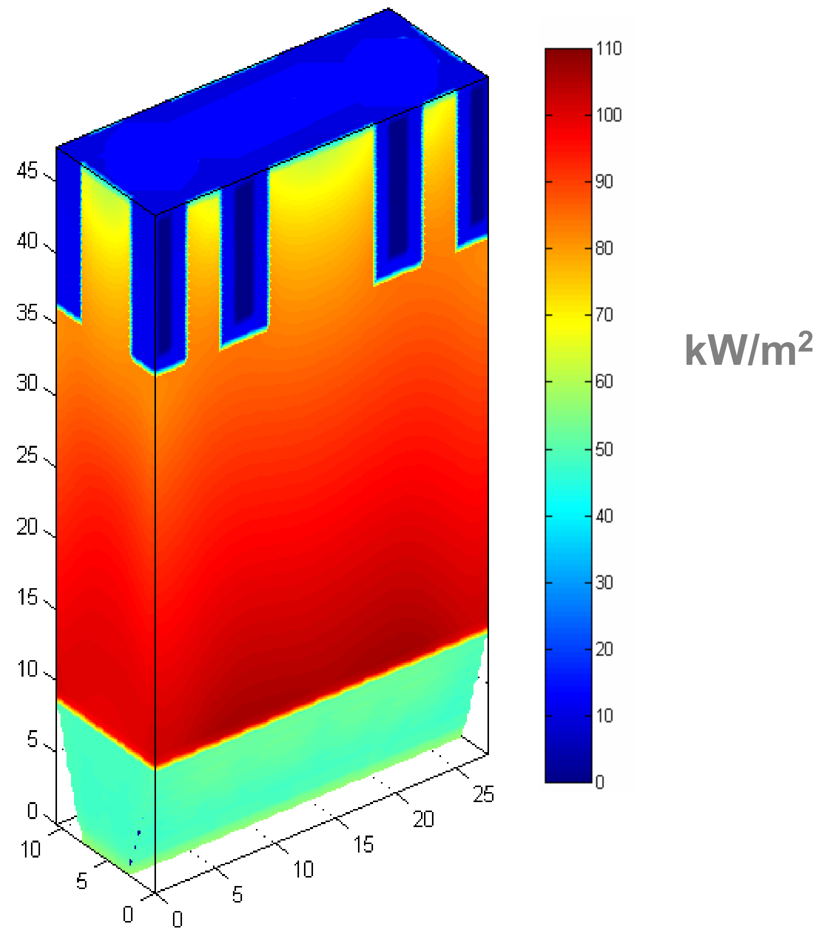


- BENSON low mass flux technology
- Furnace circuit:
  - Vertical tubing
  - Membrane walls, smooth tubes Ø38 x 8.0 mm, mass flux ~ 600 kg/m^{2}s
  - Evaporation panels, rifled tubes Ø51 x 8.8 mm, mass flow flux ~ 600 kg/m^{2}s
- INTREX casing and support in economizer circuit
- Furnace roof in primary superheater circuit
- Solid separators in tertiary superheater circuit
- INTREX-heat exchanger in final superheater / reheater circuit

Furnace Heat Transfer

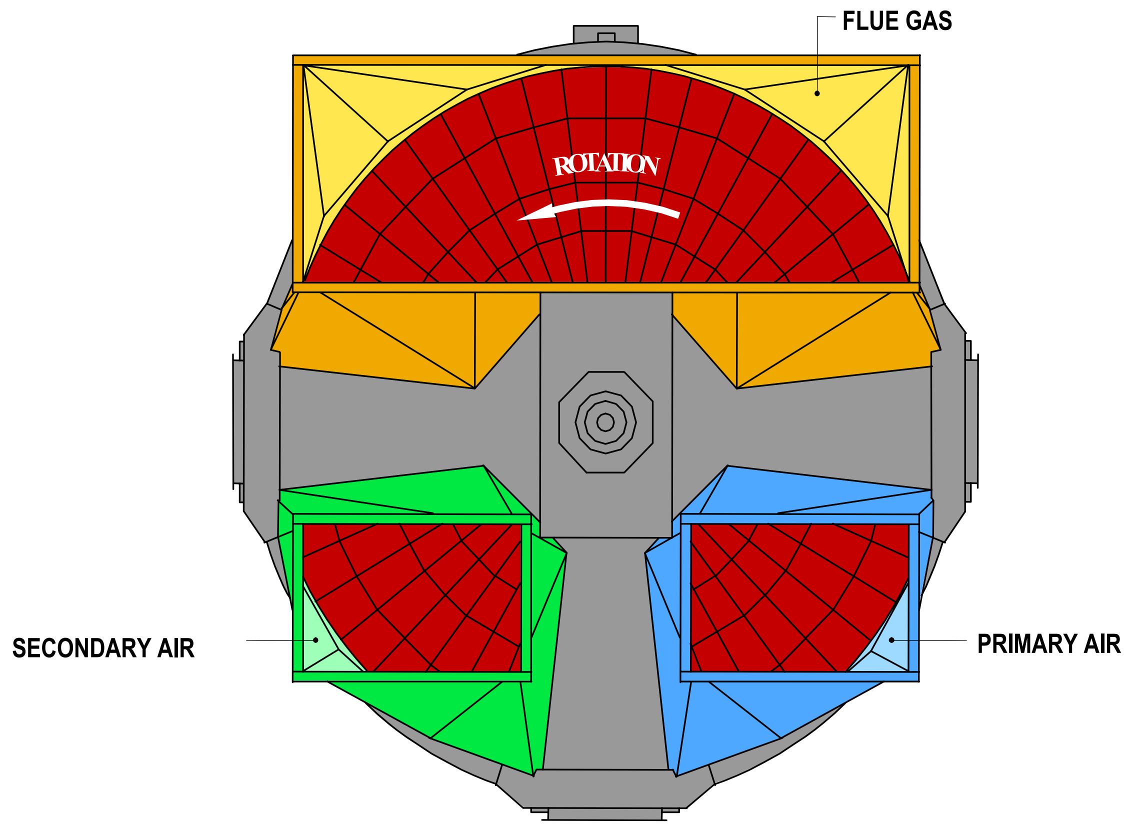
- Low and Uniform Heat Flux
- Calculated with 3D Furnace Model



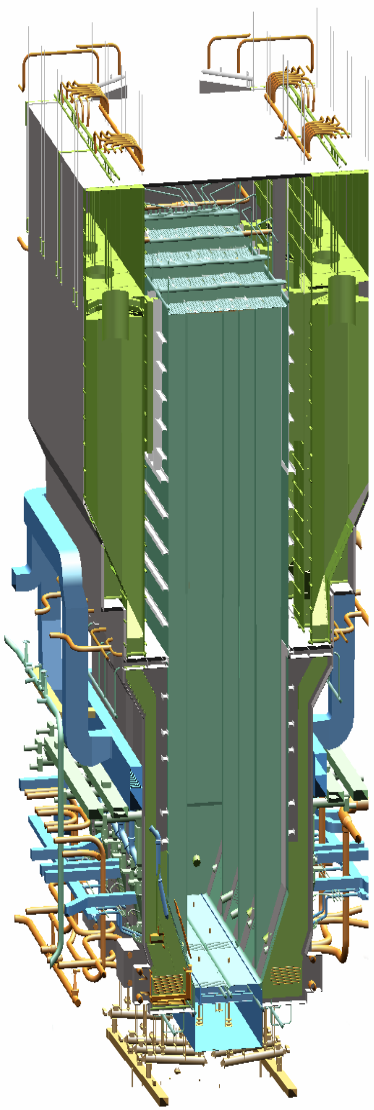


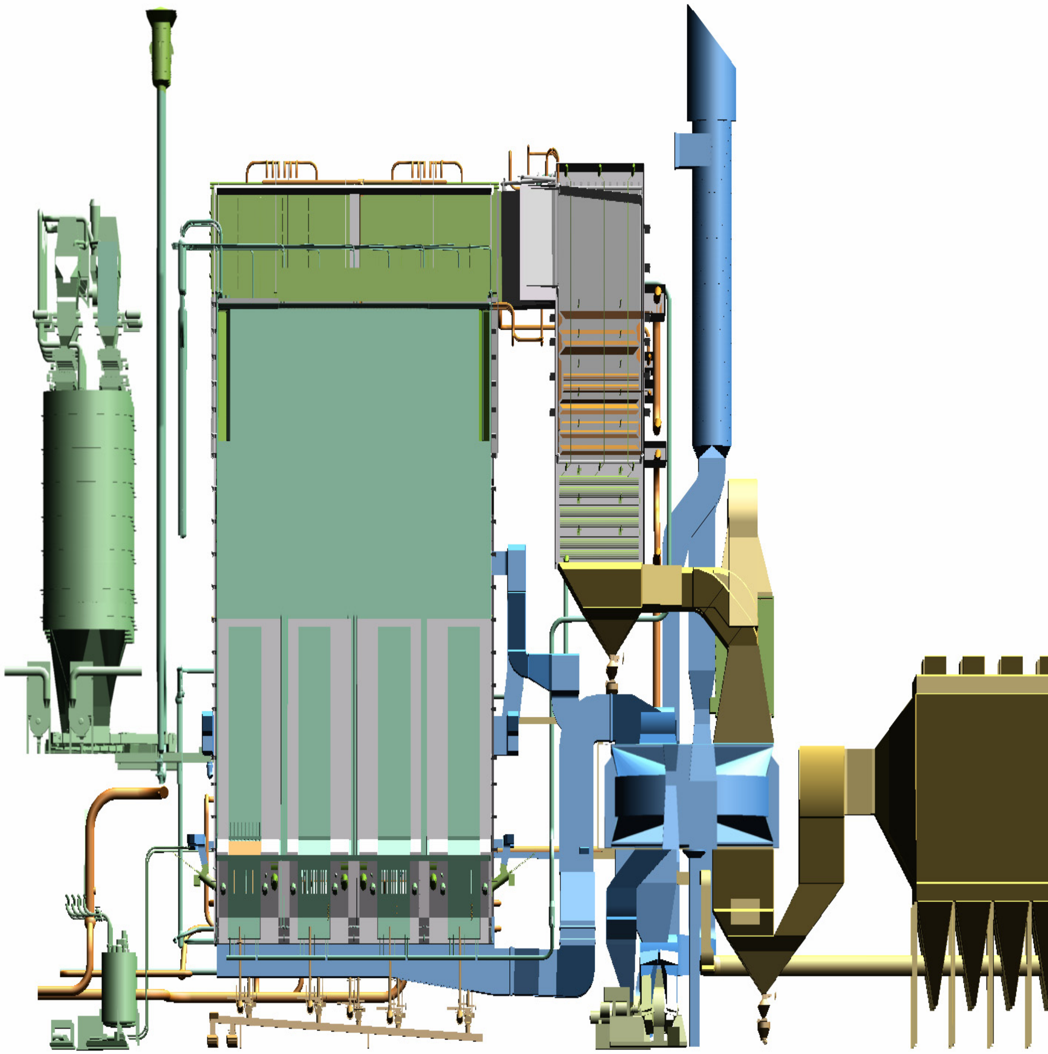
Tri-Sector Regenerative Air Heater: Most Economical Option

- Low Cost Option
- Low Pressure Drop
- Easy Cleaning
- Compact Design
- Maintenance Required for Sealing and Drive System



Łagisza 460 MWe CFB





Furnace:

Depth: 10.6 m

Width: 27.6 m

Height: 48 m

Boiler Materials

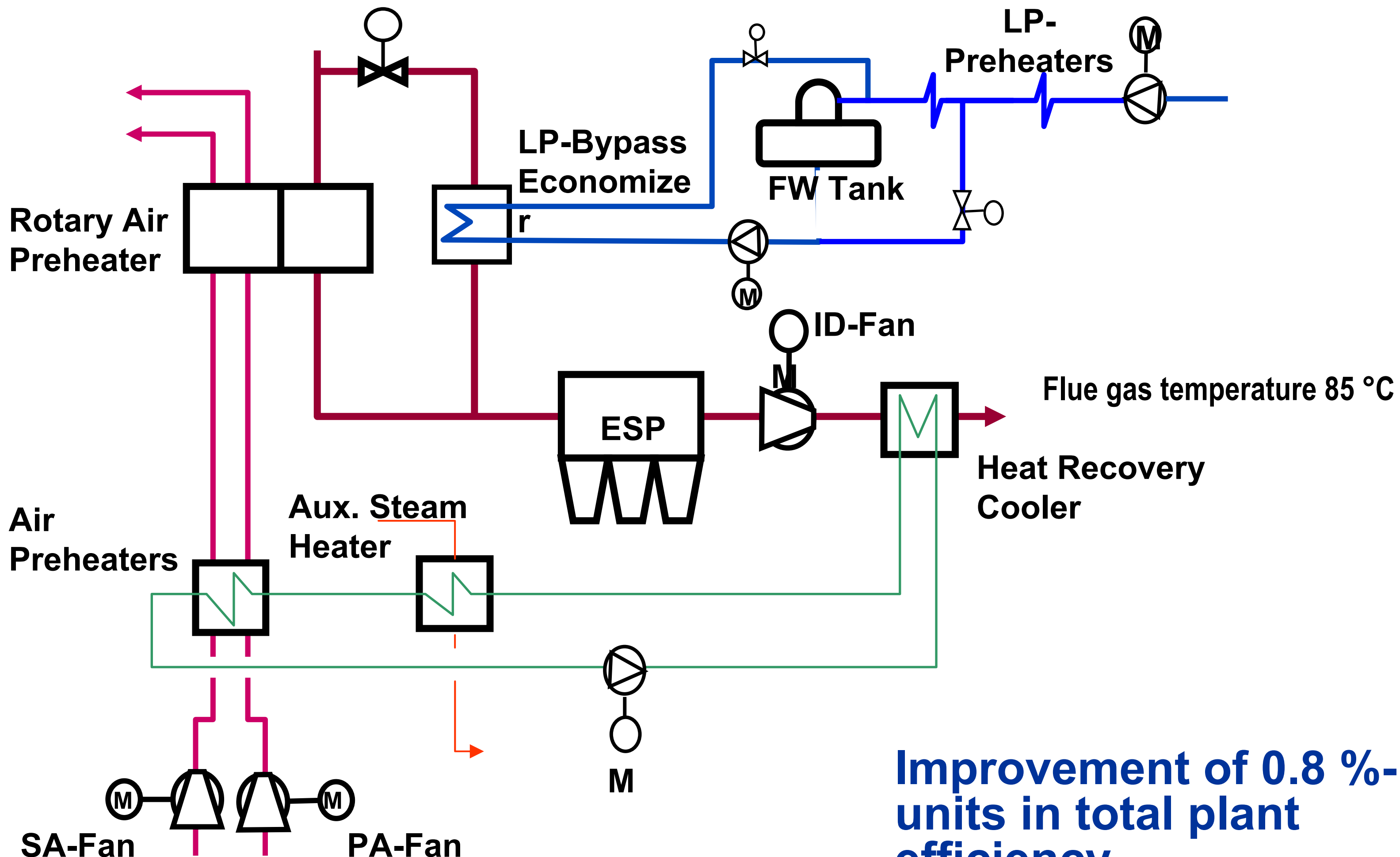
HEAT SURFACES:

- Economizer:
  - 15Mo3
- Furnace panels:
  - 13CrMo44
- Superheaters:
  - 13CrMo44
  - 7CrMoVTiB1010
  - X20CrMoV121
  - TP347HFG

HEADERS, PIPING:

- Economizer:
  - 15NiCuMoNb5
- Furnace:
  - 15NiCuMoNb5
  - 13CrMo44
- Superheaters:
  - 13CrMo44
  - X10CrMoVNb91
  - X11CrMoWVNb911
- Main Steam Lines
  - X11CrMoWVNb911

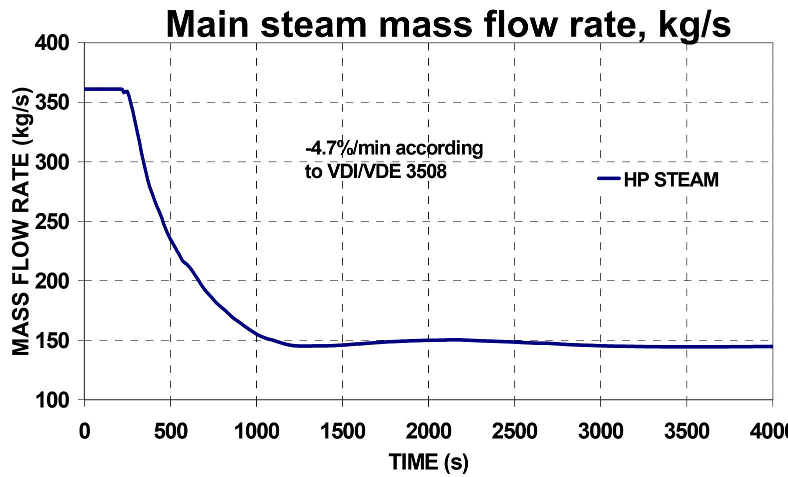
Flue Gas Heat Recovery

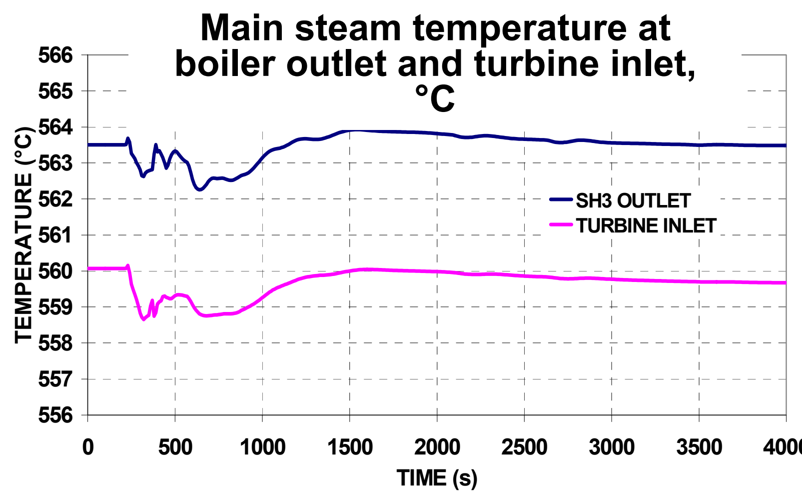


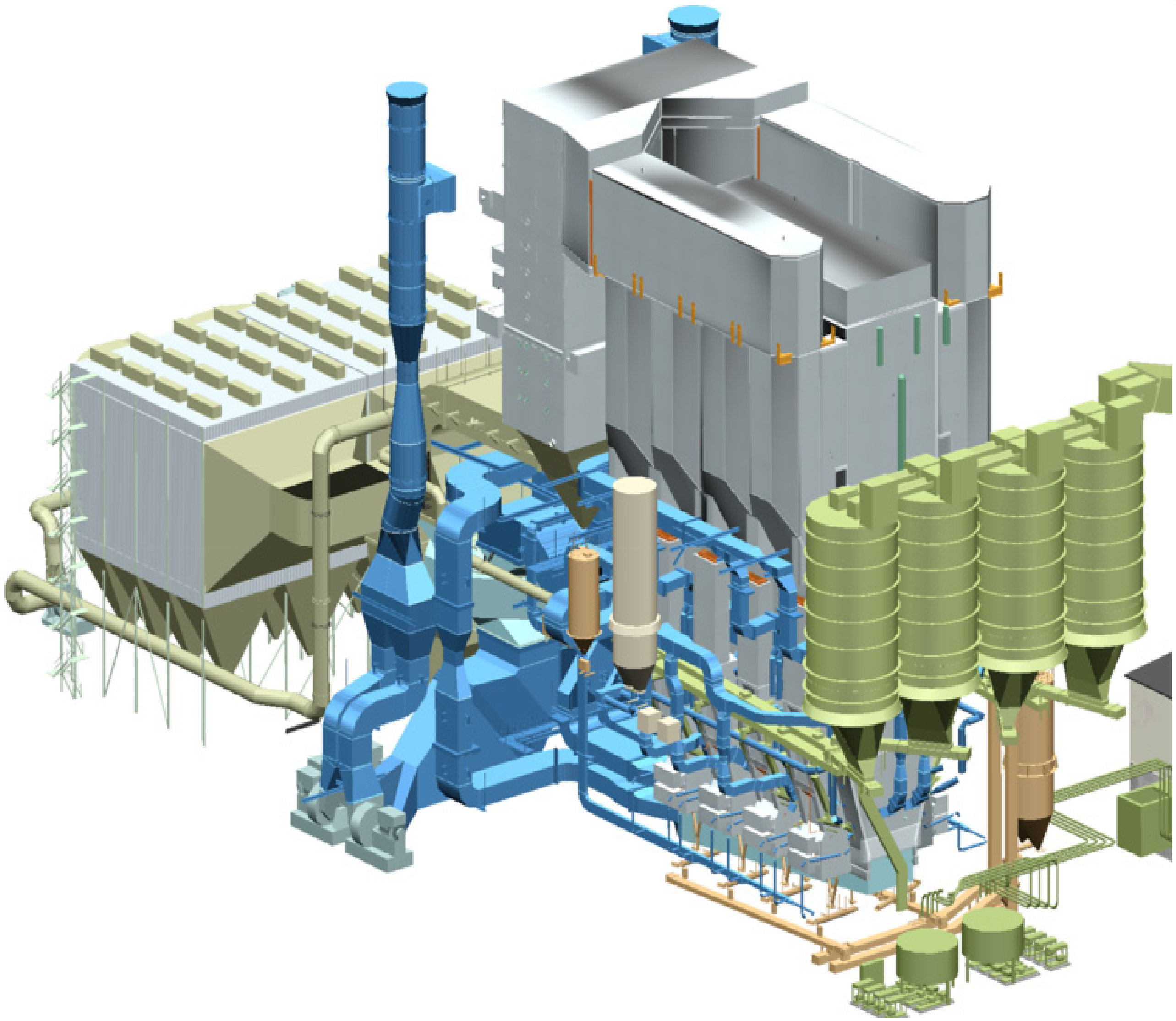
Improvement of 0.8 %-units in total plant efficiency

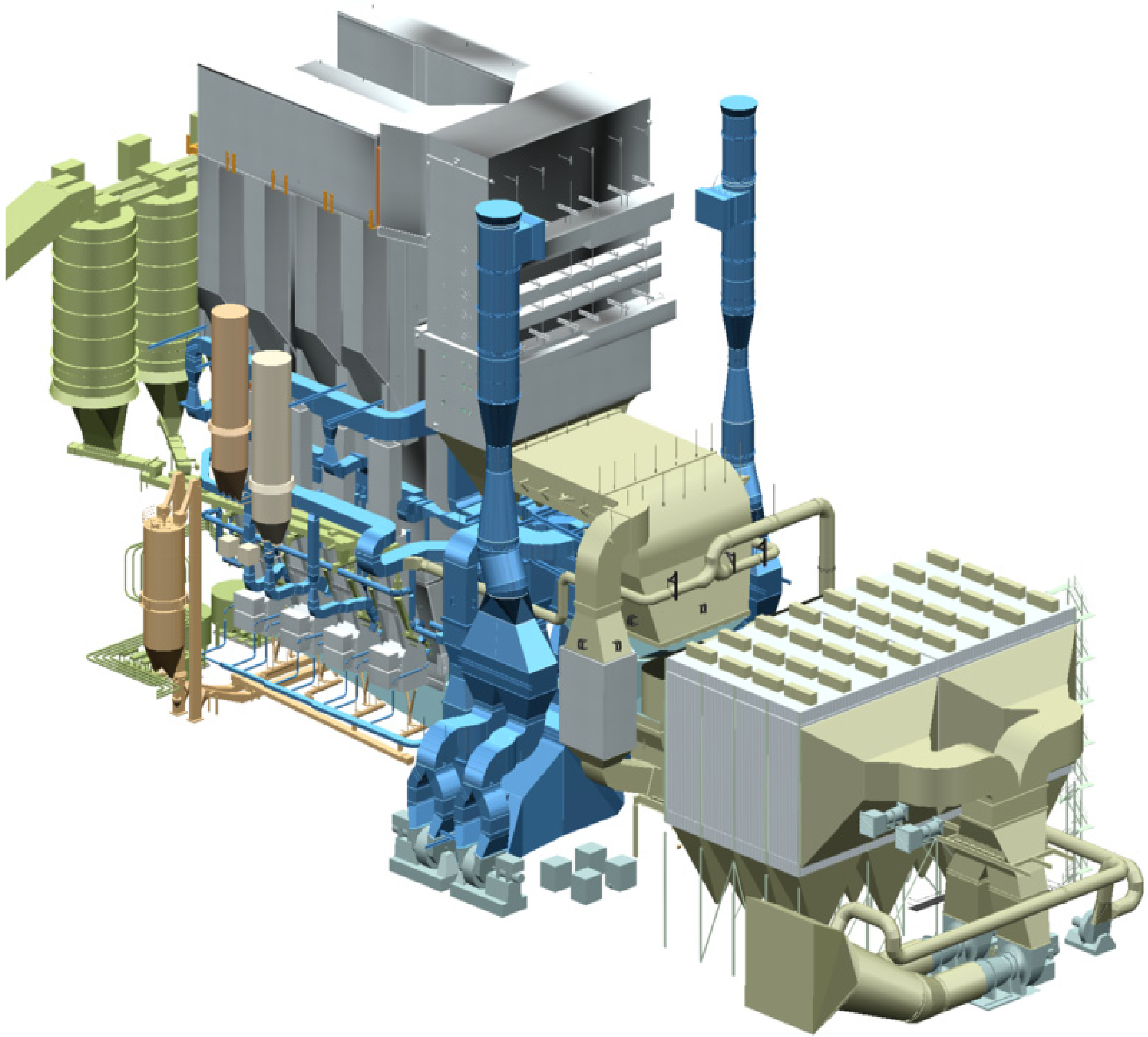
Dynamic Simulations

- Detail Simulation Models Developed for Gas/Solids and Water/Steam side
- Following situations simulated:
  - Step load changes
  - Ramp load changes
  - Boiler runbacks
  - Blackout
- Boiler fullfils electrical grid requirements









CONCLUSIONS

SUCCESSFUL DEMONSTRATION OF:

- **Large-scale CFB units in utility application**
- **Larger size CFB within the foot print of old PC unit**
- **Fast dynamic characteristics for load dispatch required by modern power grid system**

CONCLUSIONS

- **High efficiency, fuel flexibility and low emissions without additional equipments**
- **High availability and low failure frequency of CFB boilers in Poland**