Fuel Impact on Boiler Concept - outlook

2012-11-12, Värme- och Kraftkonferensen 2012

Morgondagens energisystem

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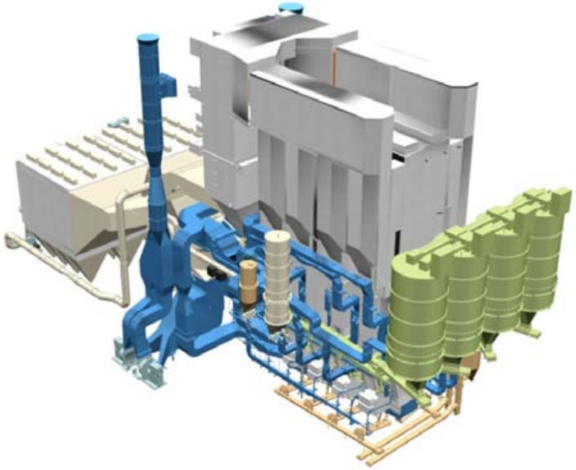
Presentation Outline

- **Solid Biomass as Energy Source & Circulating Fluidized Bed Technology**
- **Fuel characterization**
- **Boiler Design Features for Biomass Firing**
- **Key References for Biomass Firing**
  - Clean Biomass Fuels
  - Challenging Biomass Fuels

Biomass as Energy Source & Market Drivers

- Biomass has an **important role in reducing** the environmental effects **(CO_2)** of energy production
- **Biomass fuel market has changed to global** and makes possible large scale power generation of biomass alone
- In addition to the traditional clean and recycled biomasses, the trend today shows **increasing interest to applying agricultural biomass & waste**
- For the boiler supplier is important to understand bio fuel origin and treatment processes as well as the actual ranges of fuel and ash properties
- **CFB is IDEAL TECHNOLOGY for large scale power generation for broad range of biomass alone or co-firing in larger fossil fired power plants!**

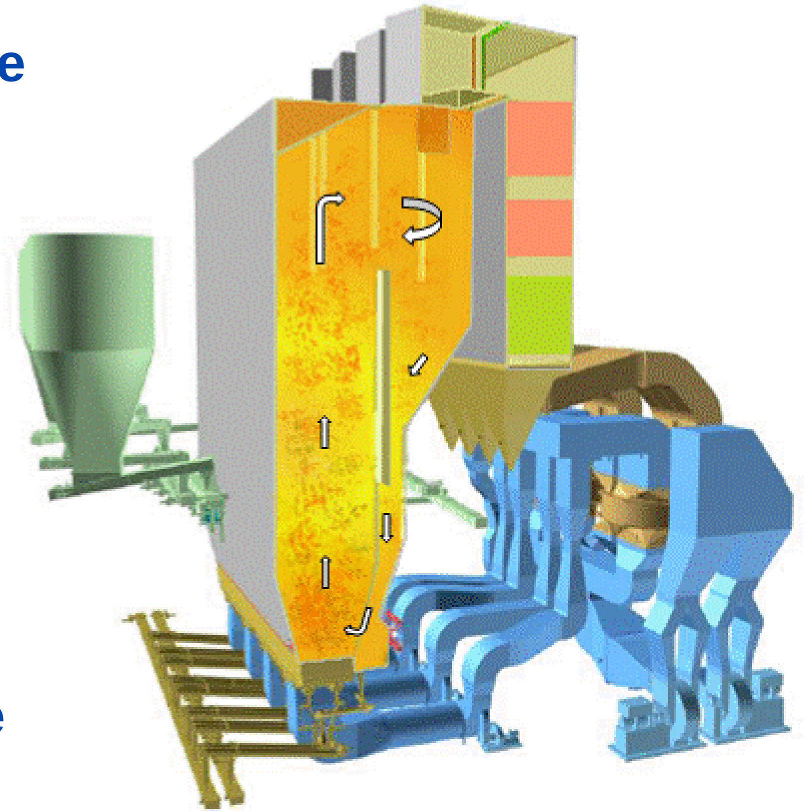


Key Advantages of CFB for Biomass Firing

- **Fuel flexibility is a special advantage**
  - Wide range for biomass fuels
  - Mixes of wood, agro, waste, etc
  - Mixes of biomass fuels, coal

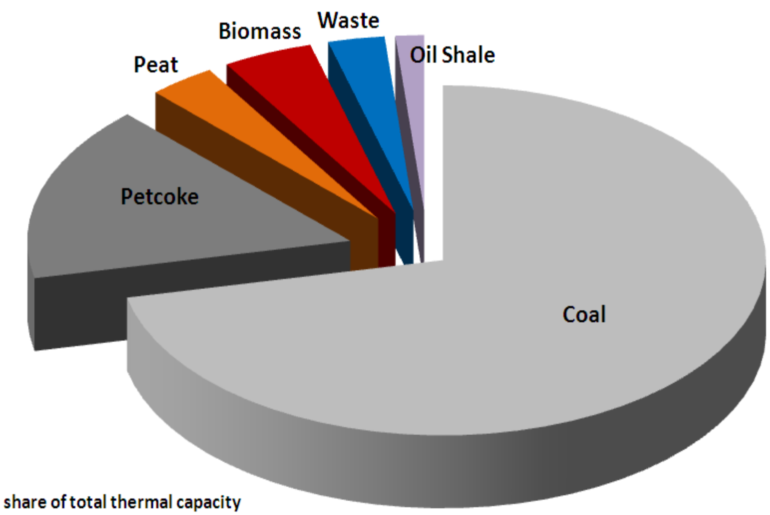
- **Excellent emission performance**
  - Inherently low emissions
  - No DeSOx / DeNOx –plants required

- **High availability & competitive price**



CFB Fuel Flexibility & Biomass Fuels

Fuel Flexibility in CFB



Coal
- Anthracite
- Bituminous
- Subbituminous
- Lignite

Waste Coal
- Bituminous Gob
- Anthracite Culm
- Coal Slurry

Petroleum Coke
- Delayed
- Fluid

Peat

Wood Residue
- Bark
- Chips
- Sawdust
- Forest Residue

Agricultural Waste
- Straw
- Olive Waste
- Sunflower Husk
- Rapeseed
- Dried Fruits
- ...

Sludge
- Paper mill
- De-inking
- Municipal

Recycled Wood

Tire Derived Fuel

Solid Recovered Fuel

Waste Paper

Gas

Natural

“Off” gases

Oil

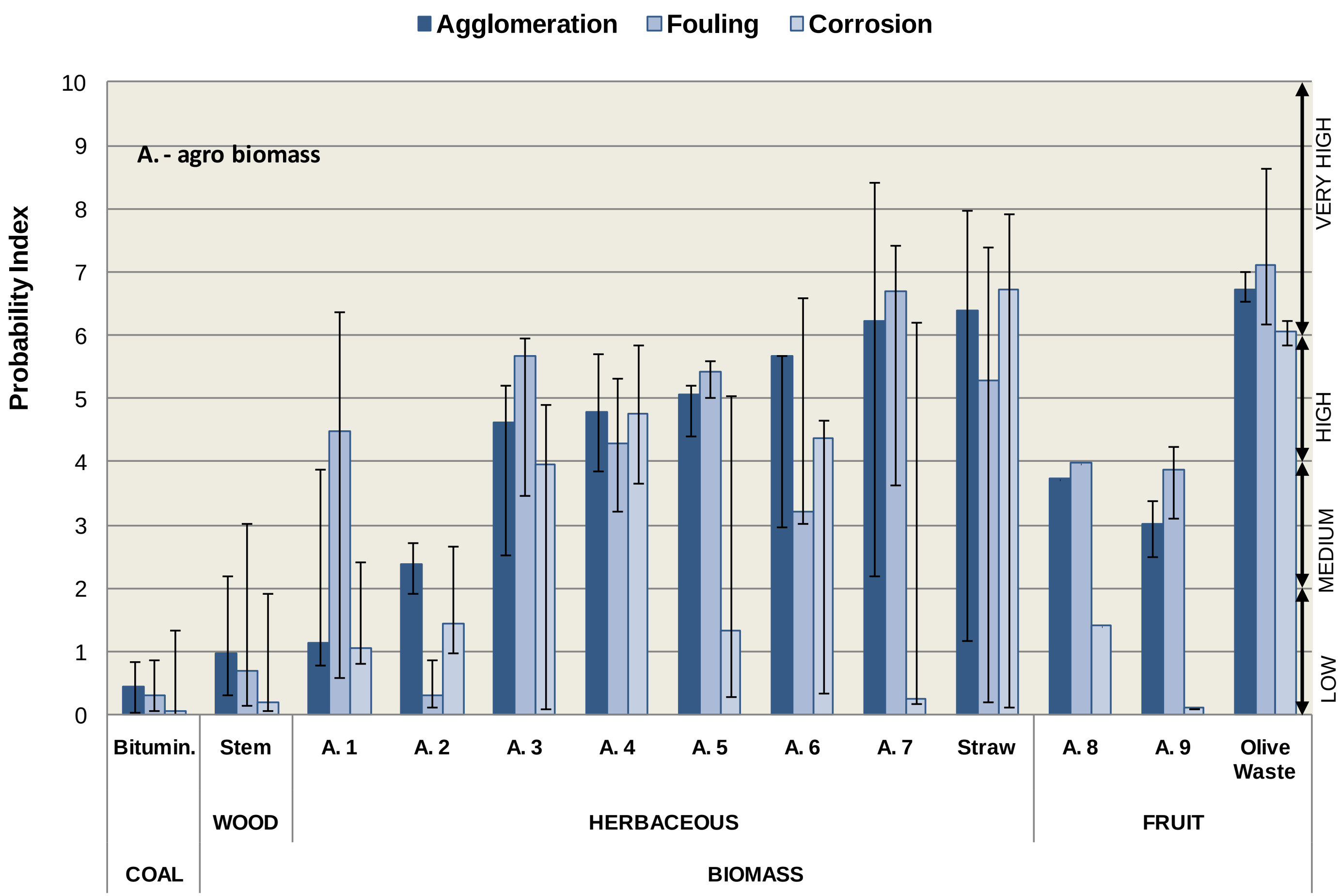
Oil Shale

Biomass Properties

	Timber pellets	Timber chips	Saw dust	Bagasse briquette	Straw pellets	Peat	Recycled wood	RDF fluff
Moisture %	5-10	20-50	45-60	8	12	50	25	25
Lower Heating Value								
MJ/kg	17	7,5-13,9	6-10	16	14,7	9,3	14	13
Bulk Density kg/m3	650	130-280	300-350	650	650	340	300-400	100
Energy density								
MWh/m3	3	0,55	0,45-0,7	2,9	2,7	0,9	1,4	0,4
Ash % ds	0,9	0,4-5,3	0,4-0,5	6	7	5,1	5	10-20
S % ds	<0,1	<0,1	<0,05	<0,05	0,01-0,03	0,22	0,1	0,1-0,5
Cl % ds	<0,03	<0,05	<0,03	<0,03	0,1-0,8	0,02-0,06	0,1	0,3-1,2
Alkali % ds	0,1-0,3	0,1-0,3	0,1-0,3	0,4-0,7	0,3-1,7	0,1	0,1-0,5	0,4-1
P % ds	<0,05	<0,05	<0,04	<0,05	0,05-0,8	<0,35	<0,3	<0,5

- High concentrations of alkalis and chlorine increase risk for agglomeration, fouling and corrosion

Prediction tools for fuel effects and corrosion estimation



Agglomeration, Fouling and Corrosion probabilities for selected fuels based on FW AFC model

Boiler Design Features for Biomass Firing

Factors Effecting for Boiler Concept

Fuel Characterization

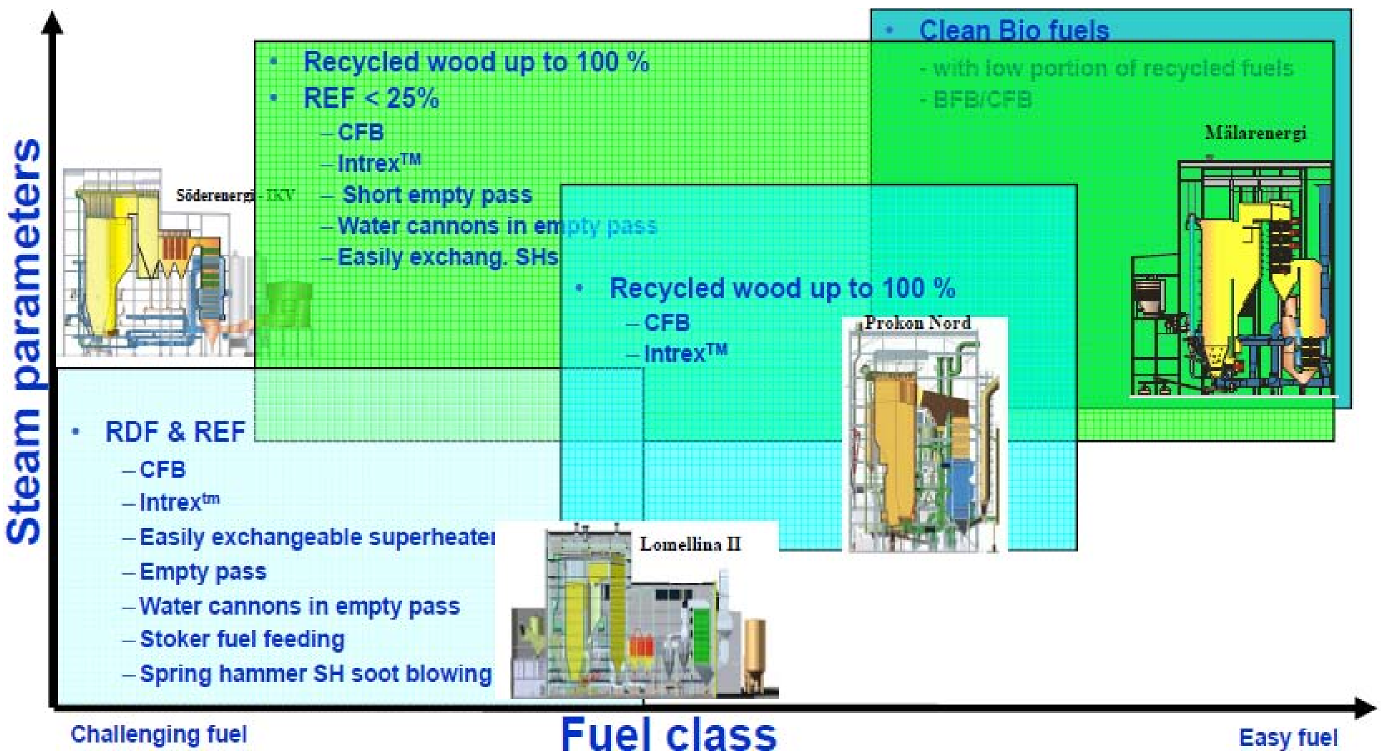
- Physical & Chemical characteristics
- Fouling characteristics
- Corrosion characteristics

Plant Requirements

- Utility / Industrial
- Steam data
- Emissions
- Legistlation

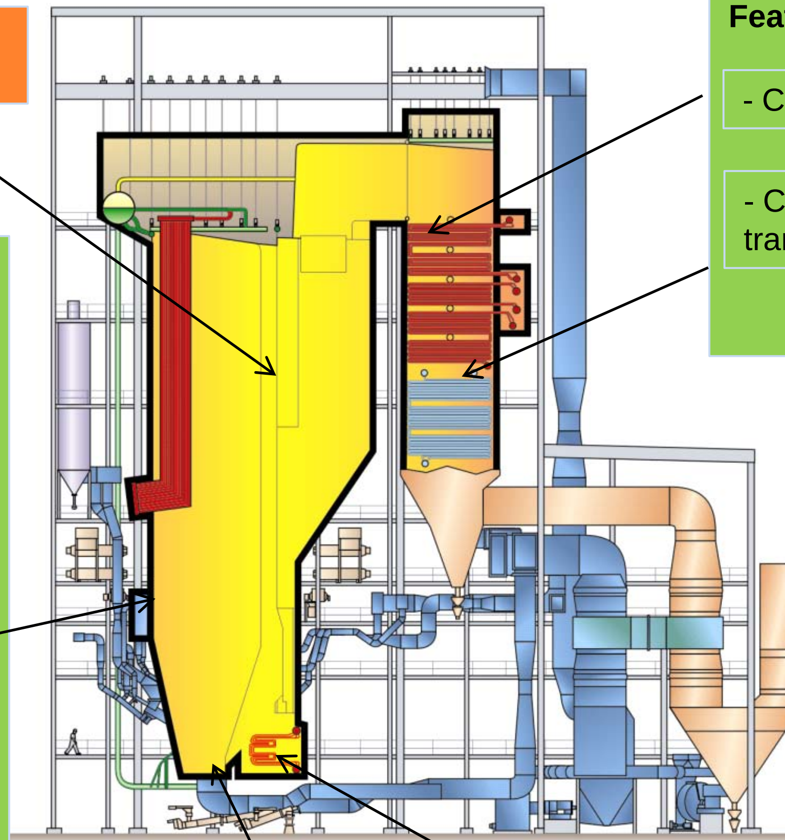
Investment Factors

- Investment cost
- Operation cost
- Fuel flexibility
- Availability



Design Features for challenging fuels

Integrated Water/Steam Cooled Solid Separator and Return Leg



Features to control Fouling & Corrosion

- Correct flue gas temperature

- Correct design for convective heat transfer surfaces

Features to control Agglomeration & Fouling

Effective temperature control

Conservative flue gas velocity

Possibility to use Additives with worst quality agros

Active Bed Material

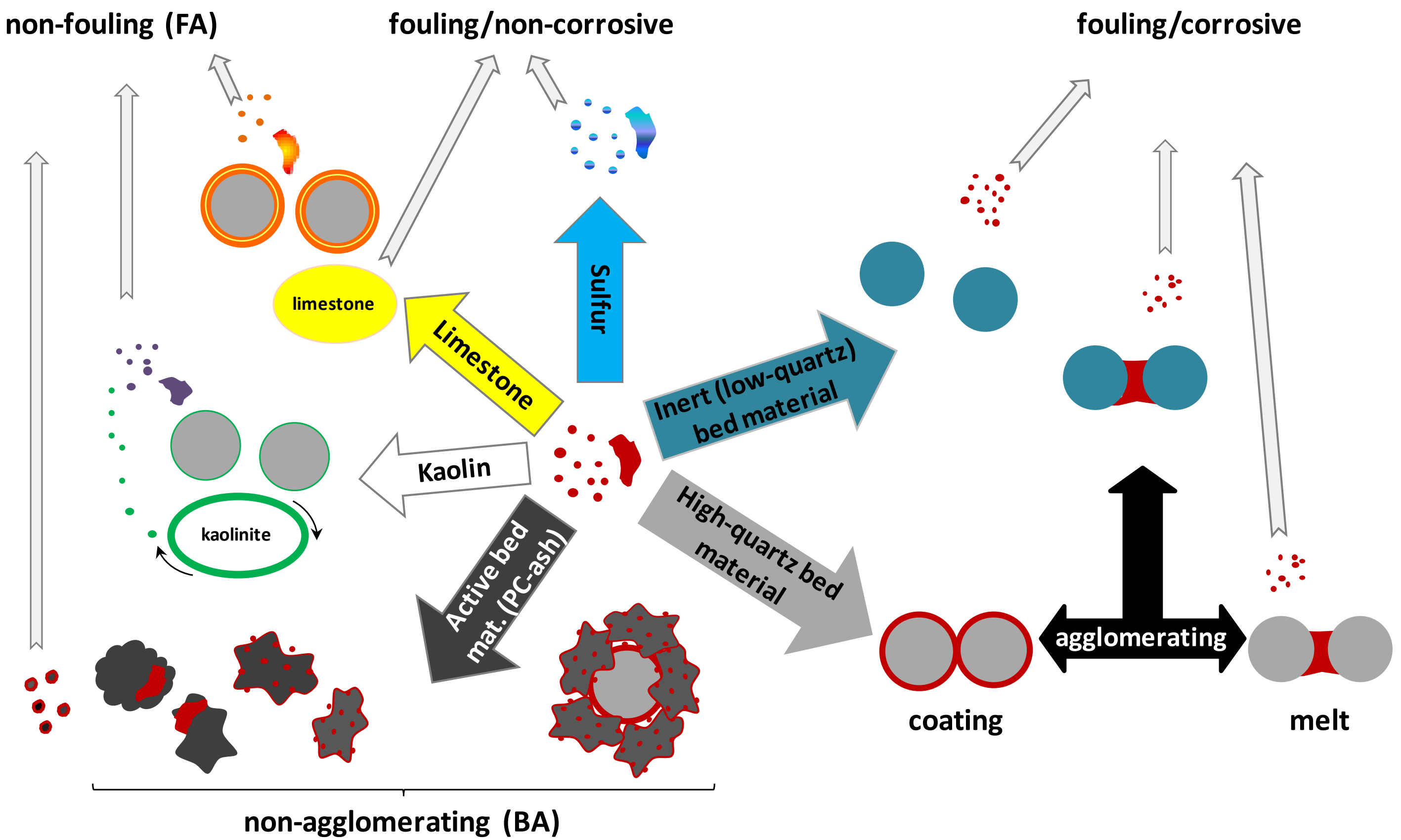
During Operation:
- Fuel quality management
- FW SmartBoiler datalog & Diagnostic tools

Step Grid

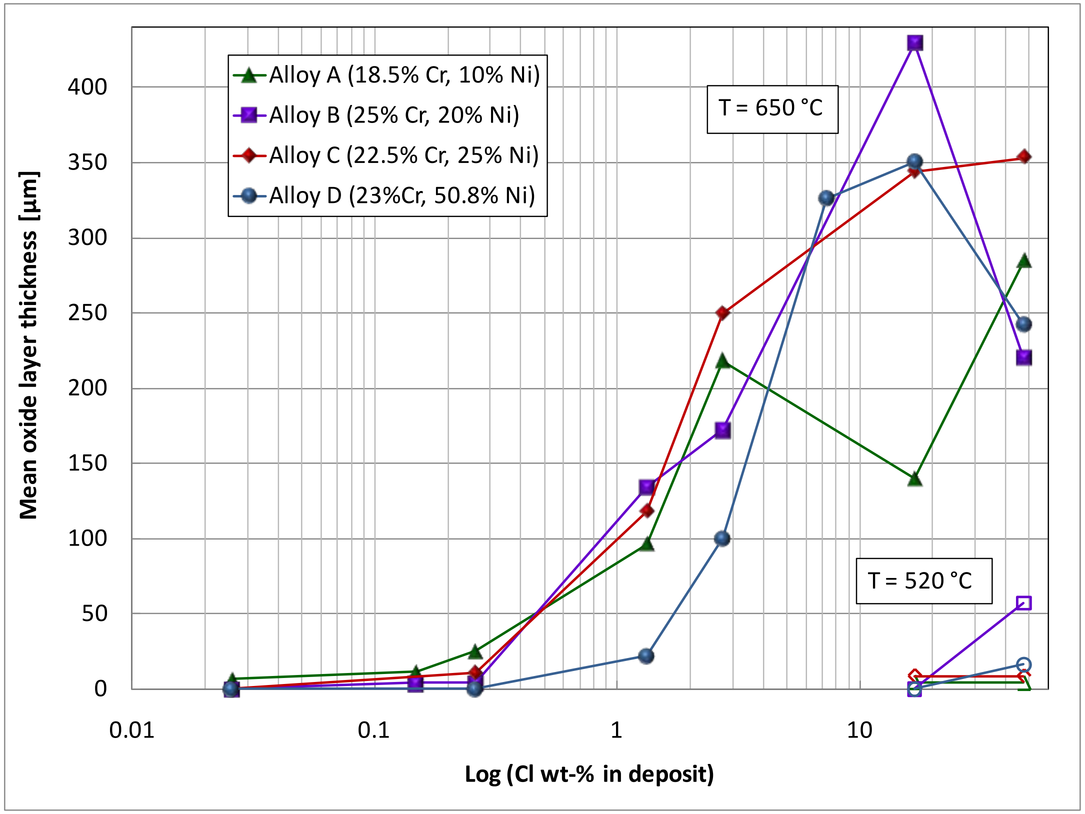
Final SH & RH as INTREX

Additives and alternative bed materials against Agglomeration, Fouling and Corrosion

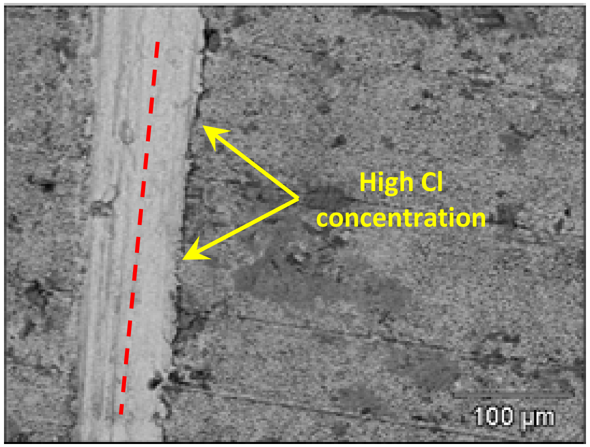
Schematic representation of mechanisms observed between fuel ash, bed materials, and additives



The role of alloying elements against fire-side Cl-induced corrosion >600 C



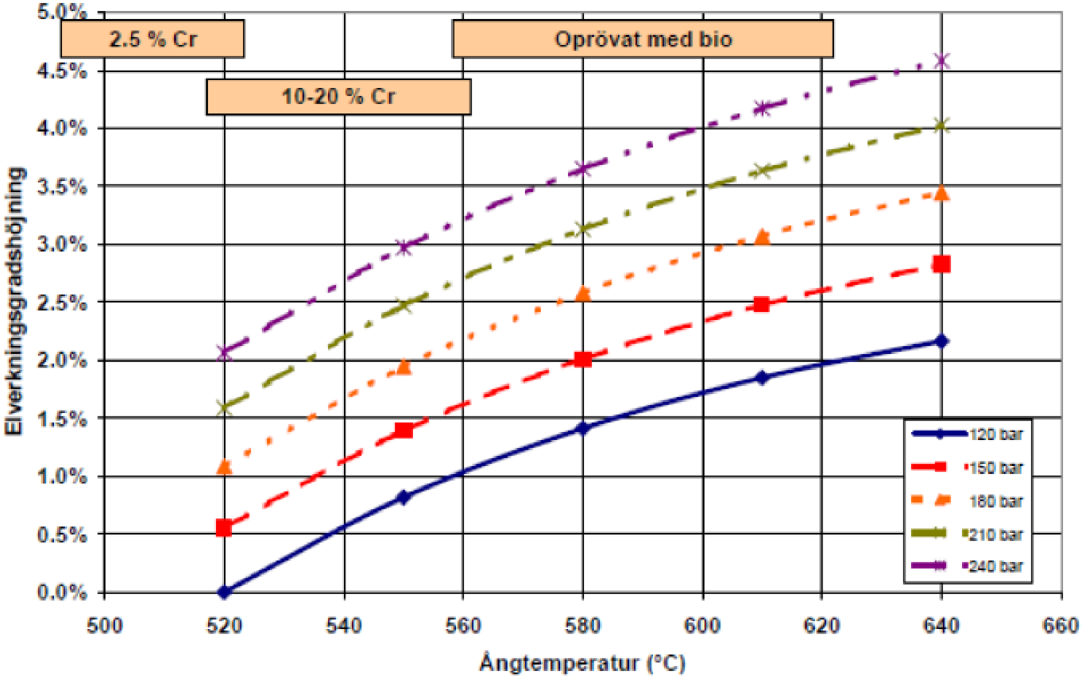
Laboratory corrosion test results



Deposit from commercial CFB co-firing high share of agro with coal (408 hours)

- High Cr, or high total alloying elements do not guarantee low corrosion
- Other material properties such as stabilizing elements and crystallographic structure gain a bigger role at temperatures > 600 C

Materials availability for higher efficiency boilers



Figur 10. Elverkningsgradshöjning som funktion av ångtemperatur vid olika ångtryck för en"avancerad" ångcykel med indikerade materialval [3]

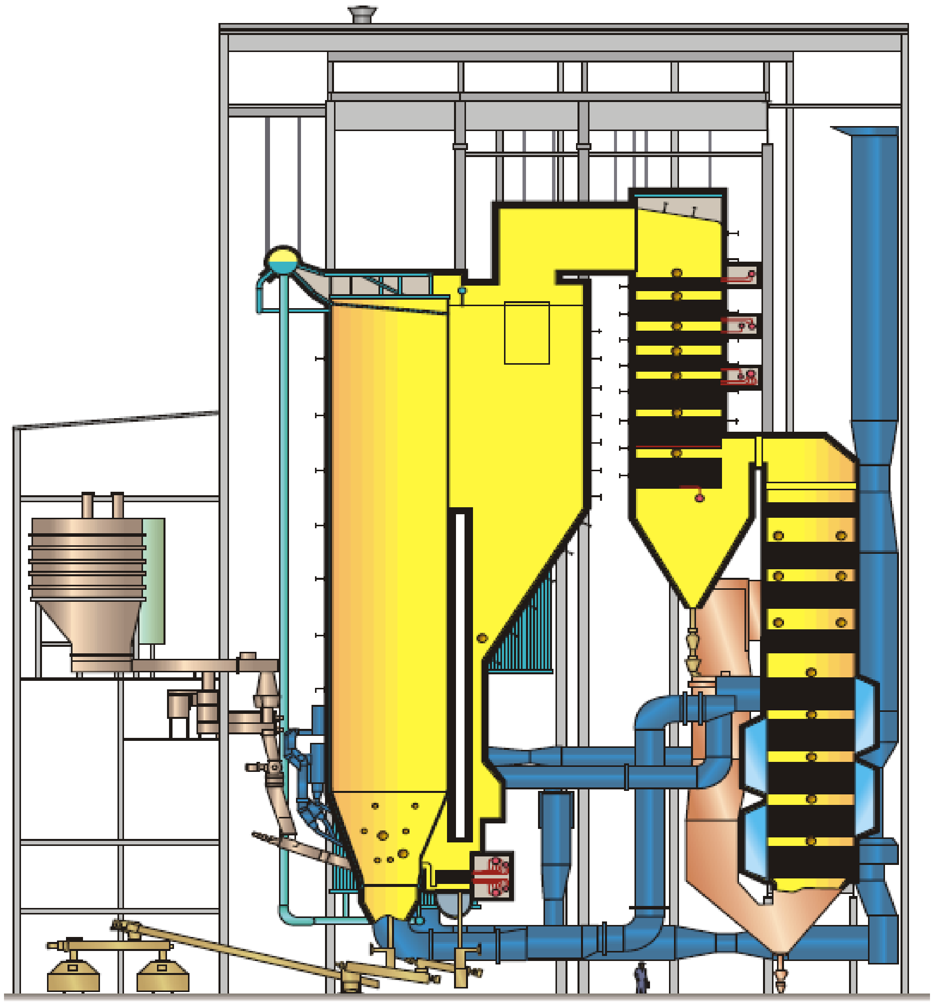
Figure 10 Increase of electric efficiency as a function of steam temperature at different steam pressures for an "advanced" steam cycle with indicated material choices

Materials for higher steam temperatures (up to 600°C) in biomass and waste fired plant.
– A review of present knowledge
Annika Stålenheim and Pamela Henderson

References for Biomass Firing

Biomass CFB, Västerås
Increased capacity with wider fuel range

180 MW_{th} (originally 157 MW_{th}), 170/39 bar, 540/540   C



Fuel mix		
Forest residues	$[\%]_{LHV}$	35
Wood chips	$[\%]_{LHV}$	10
Bark	$[\%]_{LHV}$	5
Saw dust	$[\%]_{LHV}$	5
Peat	$[\%]_{LHV}$	15
Willow	$[\%]_{LHV}$	5
Demolition wood	$[\%]_{LHV}$	25

Emissions		$6\%O_2$, dry
NOx	[mg/m^{3}n]	65
NH_3-slip	[ppm]	5
SO_2	[mg/m^{3}n]	130
CO	[mg/m^{3}n]	210
Dust	[mg/m^{3}n]	20

Large Scale CFB for Clean Biomass (CHP)
125MW$_e$ Kaukas, Finland

- **Owner: Kaukas Kaukaan Voima Oy**
  - **Owned by Lappeenrannan Energia Oy (46%) and Pohjolan Voima Oy (54%).**
- **Located at UPM-Kymmene paper mill site in Lappeenranta, Finland**

- **Combined heat and power plant (CHP)**

- **Project - Investment drivers:**
  - **More effective utilization of paper mill by-products**
  - **Replacing gas with cheaper biomass fuel for Lappeenranta City's electricity and district heat production (earlier 100% gas)**

– **Commercial Operation February 2010**

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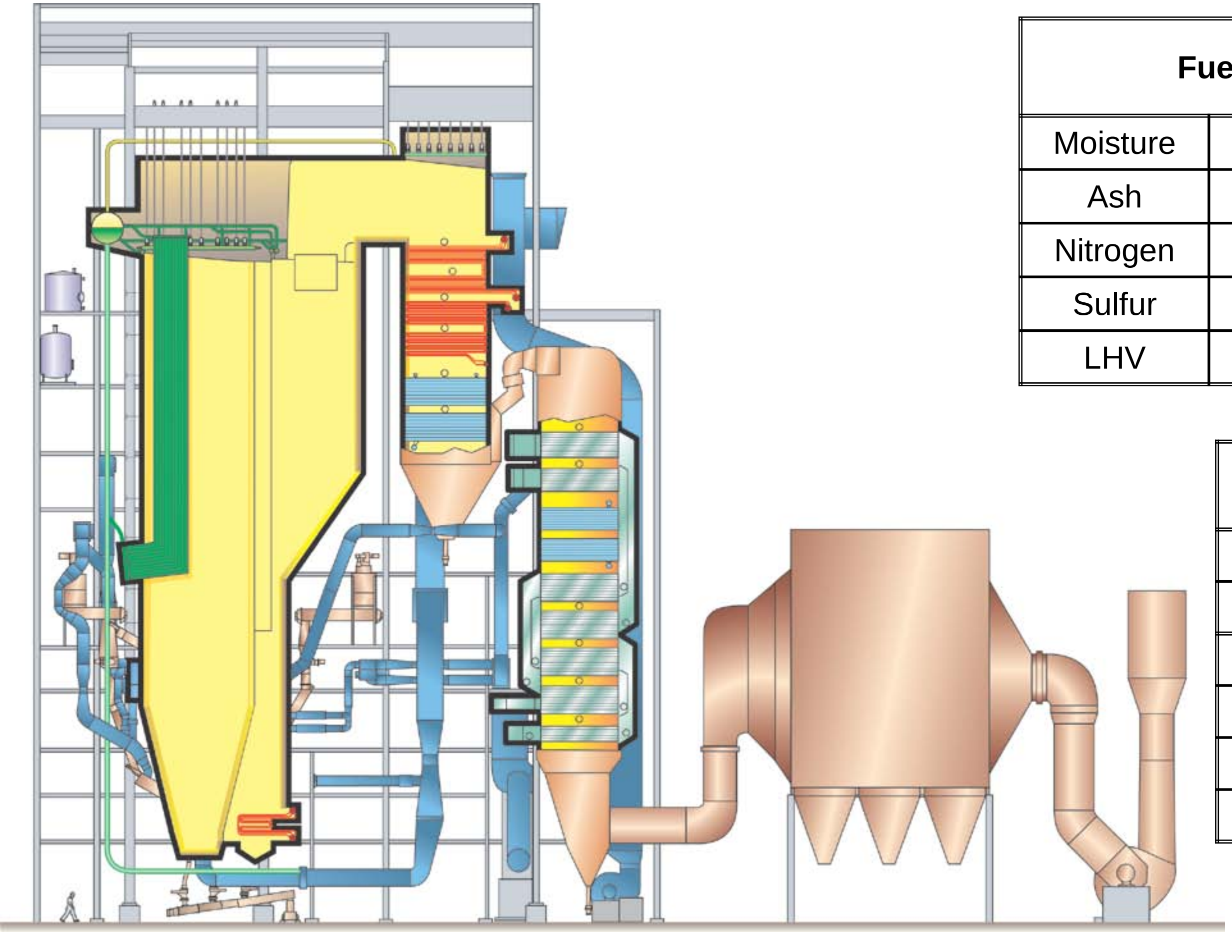
Large Scale CFB for Clean Biomass (CHP) 125MW$_e$ Kaukas, Finland

125 MW$_{e\text{-}net}$, 110 MW$_{DH}$, 149 kg/s, 115 bar(a), 550 C



Fuel		Biomass	Peat
Moisture	[%]$_{ar}$	48	50
Ash	[%]$_{dry}$	2.5	5
Nitrogen	[%]$_{dry}$	0.6	1.9
Sulfur	[%]$_{dry}$	0.05	0.2
LHV	[MJ/kg]$_{ar}$	9.2	8.5

Performance		Biomass
Flue gas T_{exit}	[˚C]	149
Boiler efficiency	[%]	91
NOx	[mg/m^{3}n]	150
SO_2	[mg/m^{3}n]	200
CO	[mg/m^{3}n]	200
Dust	[mg/m^{3}n]	20

" The Power Plant was the World's largest user of solid biomass fuels in 2010!"

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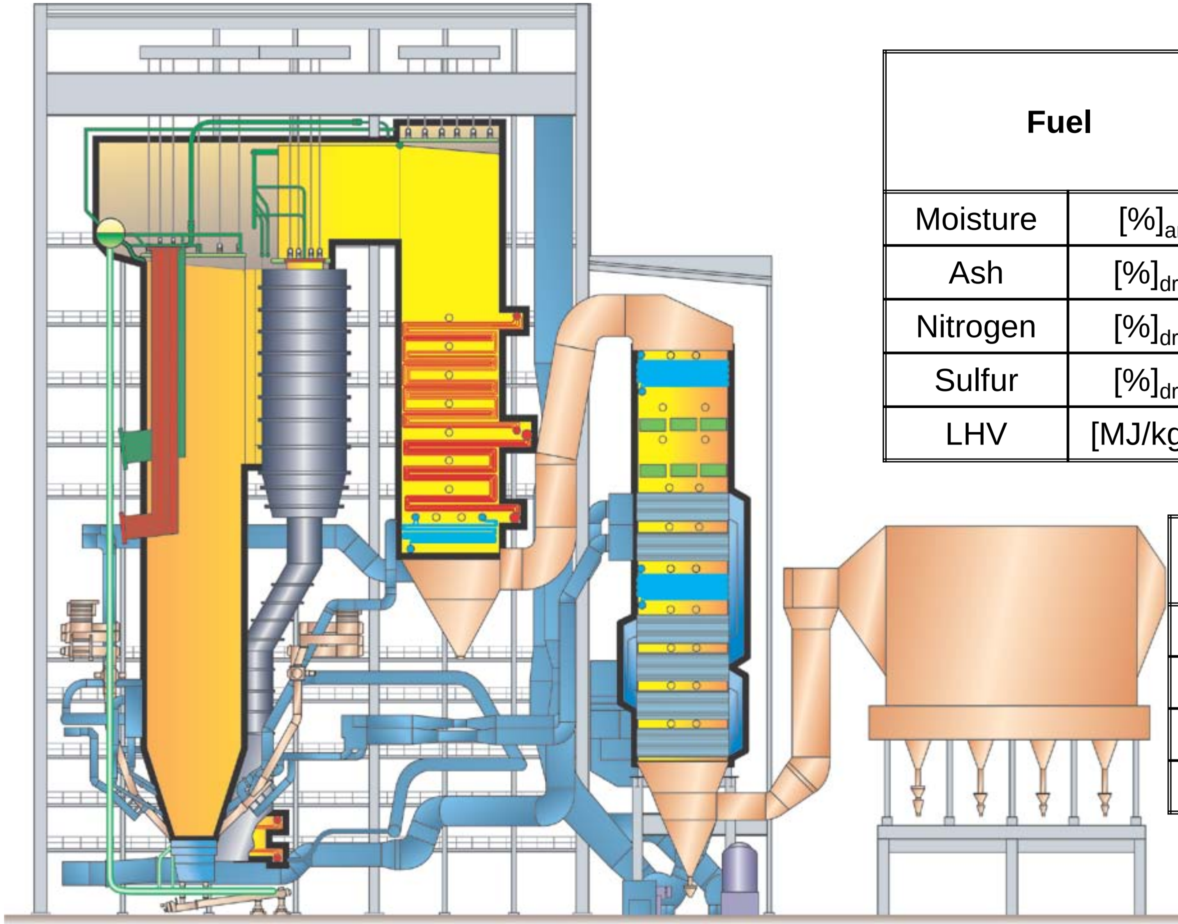
Advanced Bio CFB Concept for 20%-w Agro 205MW$_e$ Polaniec, Poland

- **World's Largest pure solids Biomass Fired Power Plant**
  - **80% wood chips & 20% Agro**
- **447MW$_{th}$, 535/535ºC, 127/20 bar(a)**
- **Re-powering from Coal to Biomass**
- **Customer: GFD Suez Energia Polska S.A**
- **Contract Award 2/2010**
- **Commercial operation 12/2012**

Advanced Bio CFB Concept for 20%-w Agro $205MW_e$ Polaniec, Poland

447 MW_{th}, 190MW_e, 535/535ºC, 127/20 bar(a)



Fuel		80% Wood Chips & 20% AGRO (Straw, Sunflower etc)
Moisture	$[\%]_{ar}$	35.9
Ash	$[\%]_{dry}$	2.8
Nitrogen	$[\%]_{dry}$	0.25
Sulfur	$[\%]_{dry}$	0.05
LHV	$[MJ/kg]_{ar}$	10.5

Emissions		
NOx	$[mg/m^3n]$	150
SO_2	$[mg/m^3n]$	150
CO	$[mg/m^3n]$	50
Dust	$[mg/m^3n]$	20

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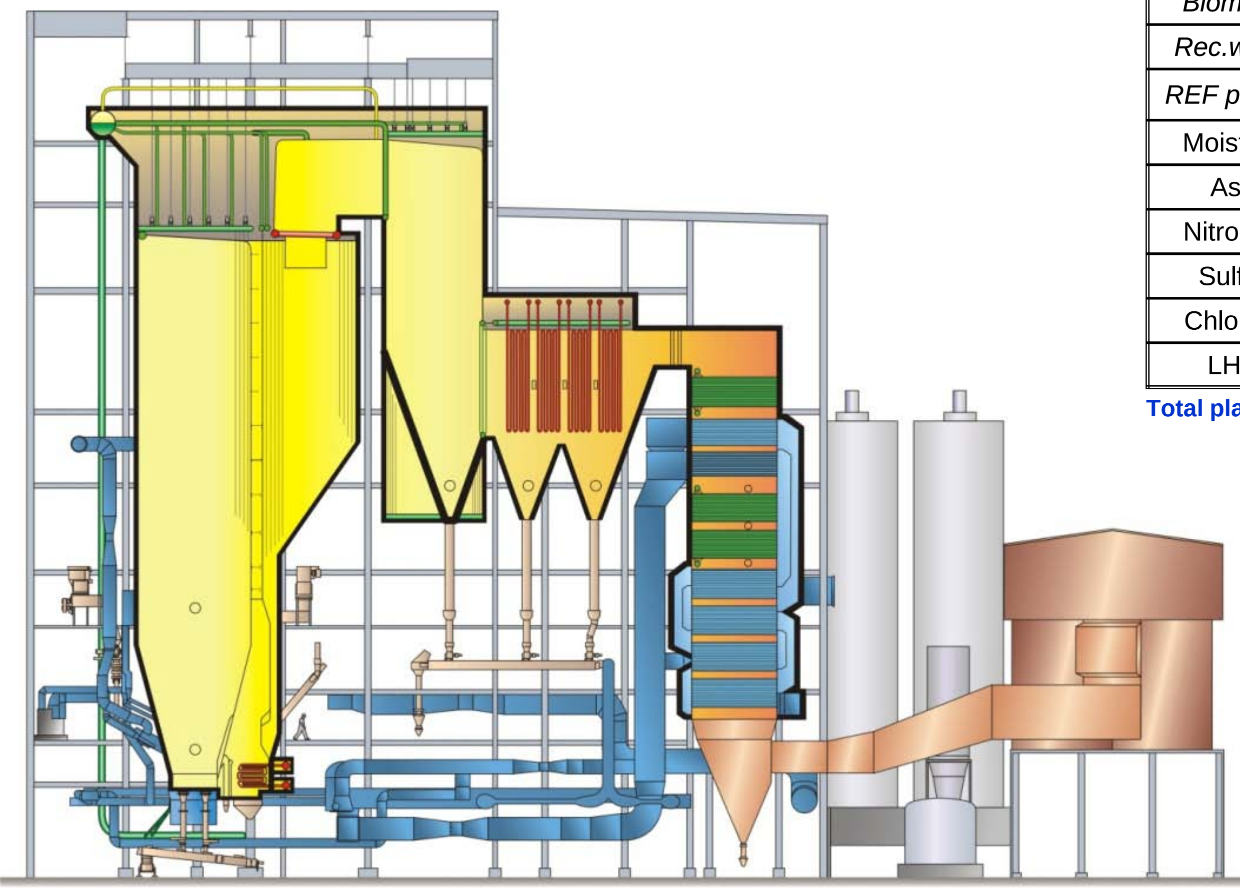
Multifuel CFB for Waste and Clean Biomass (CHP) Igelsta (Söderenergi AB, Södertälje)

240 MW_{th}, 73 $MW_{e\text{-}net}$, 209 MW_{DH}, 92 kg/s, 90 bar, 540 C



Fuel		Mix 1	Mix 2	Mix 3
Biomass	*[%]$_{LHV}$*	75	30	100
Rec.wood	*[%]$_{LHV}$*	0	70	0
REF pellets	*[%]$_{LHV}$*	25	0	0
Moisture	[%]$_{ar}$	44.3	35.6	50.0
Ash	[%]$_{dry}$	6.5	4.7	4.0
Nitrogen	[%]$_{dry}$	0.6	0.8	0.5
Sulfur	[%]$_{dry}$	0.09	0.08	0.06
Chlorine	[ppm]$_{dry}$	1200	800	200
LHV	[MJ/kg]$_{ar}$	9.7	11.0	8.3

Total plant efficiency ~110%$_{LHV}$ ≡ 90%$_{HHV}$

Emissions		6%O_2, dry
NOx	[mg/MJ]	35*
SO_2	[mg/m^{3}n]	75
CO	[mg/m^{3}n]	50*
Dust	[mg/m^{3}n]	10
NH_3	ppm	10
TOC	[mg/m^{3}n]	10
HCl / HF	[mg/m^{3}n]	10 / 1
Cd+Tl / Hg / HMs	[mg/m^{3}n]	0.05 / 0.05 / 0.5
PCDD+F	[ng/m^{3}n]	0.1

*) only at 100% load with Mix 1, 2, and 3

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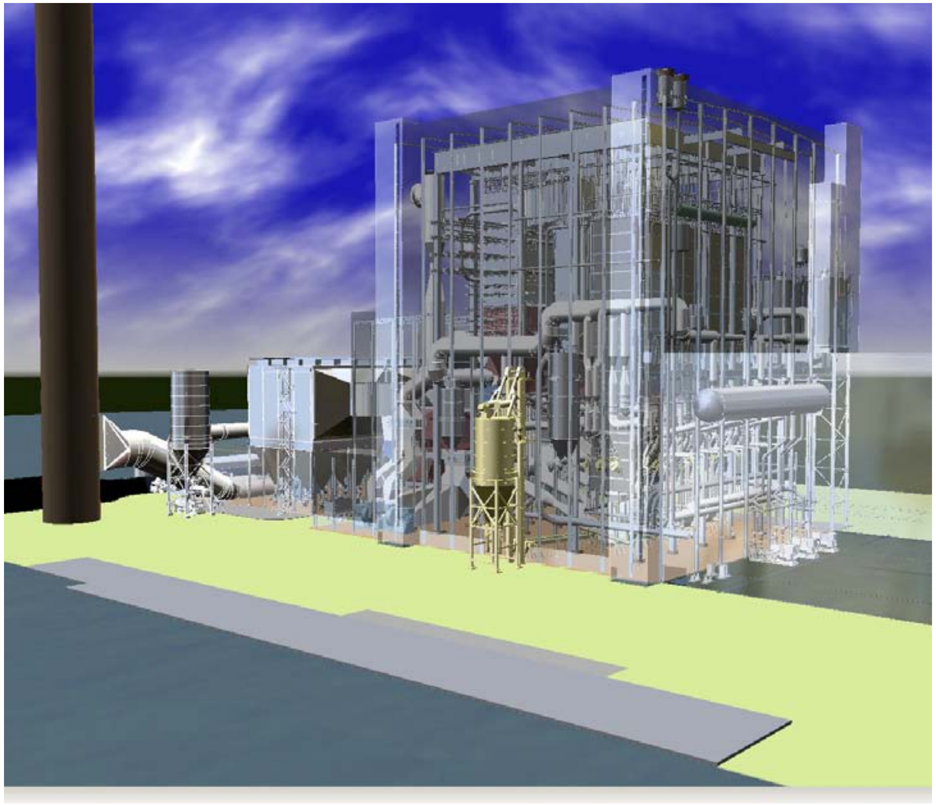
Advanced Bio CFB Technology with Pure Solid Biomass up to scale 600MW$_e$ with Sub-Critical Steam Parameters

568/566ºC, *175-190*/43.6 bar(a)

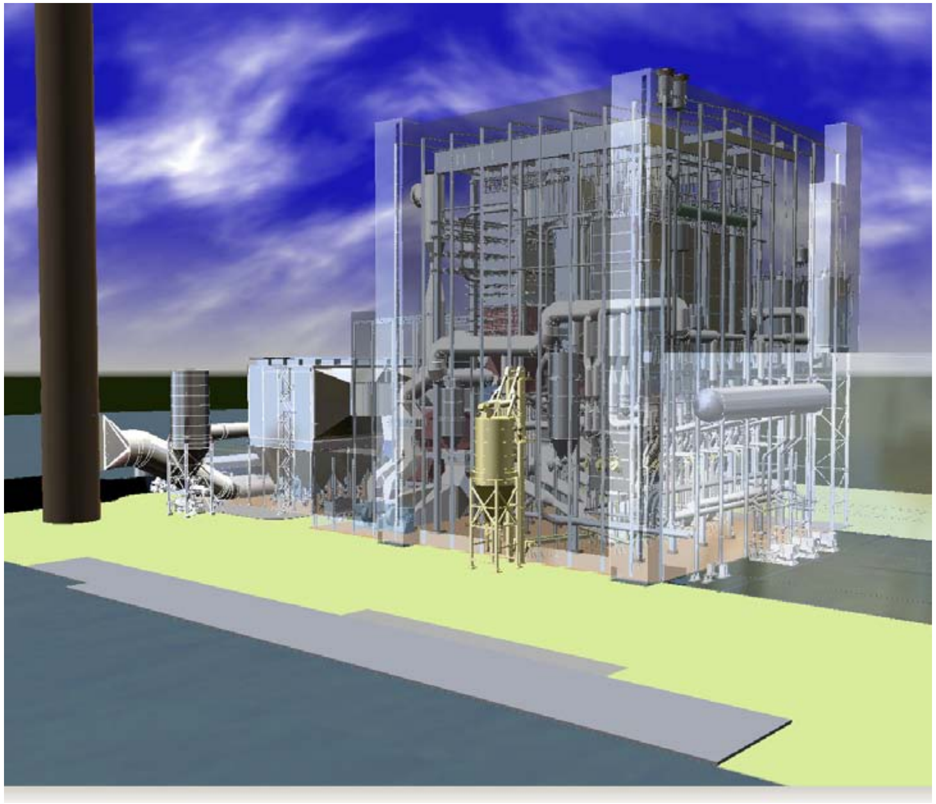


- **Market Prospects today up to 300 - 400MW$_e$**
- **CFB Technology available up to 600MW$_e$**

- **Natural Circulation Evaporator (~175bar)**
- **Once Through Benson evaporator (~175-190bar)**
  - **Lower Investment cost in large scale**
  - **High plant efficiency over the whole load range**

Large Scale and High Efficiency Advanced Bio CFB Concept for 20-30%-w Agro with Clean Biomass up to scale 400MW_e

568/566ºC, *179-190*/43.6 bar(a)



- Natural Circulation available up to 400MWe (~179bar)
  - Limiting factor for scale in EU is drum manufacturing capability (up to scale ~350MWe)
- Once Through Benson available up to 400MWe (~179-190bar)
  - Lower Investment cost in scale ~350-400MWe
  - Limiting factor for steam pressure is corrosion resistance of evaporator panel wall

Take Away,,

- **Biomass has an important role in reducing the environmental effects of energy production.**

- **CFB technology is an ideal Technology to be used for power generation with broad range of solid biomass fuels, comprising of 20 % agro biomass in the recent projects commissioned this year.**

- **CFB Technology with pure biomass firing available up to 600 MW_e scale.**

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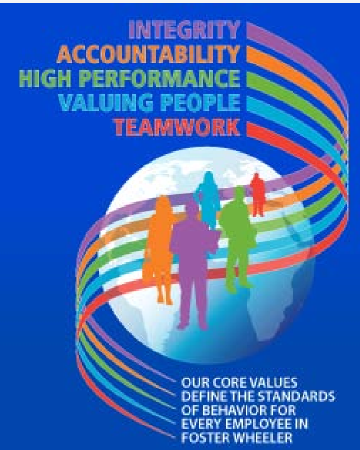
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