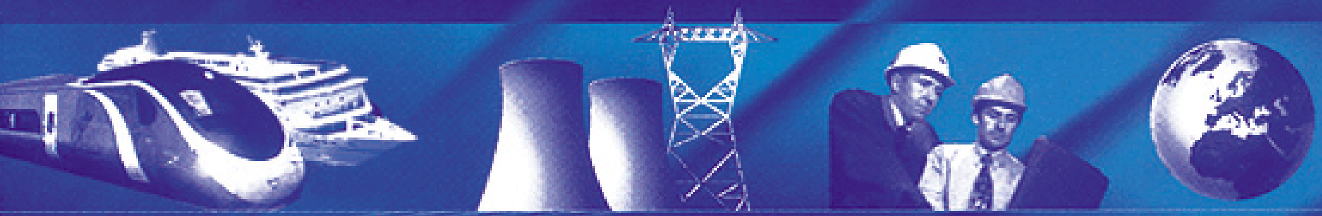

7th May, 2003

Controlling Fossil Power Plant CO_2 Emissions

Near Term and Long Range Views

Carl Bozzuto

VP Technology, Power Environment Sector

ALSTOM

Fossil Fuels

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- Fossil Fuels are the mainstay of today's economy and will be needed for a long time to come.
- Coal provides over half of the US electricity generation. Coal will be needed for electric generation well into the future. Coal is a domestic resource which can be stored to reduce price volatility.
- Natural gas sets the targets for emissions from power plants. Our goal is to make the other fuels comparable to gas in regard to emissions.

Average Emission Rates - NSPS

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	Coal g/kwhr	Gas g/kwhr
NOx	0.7	0.2
SO2	3.0	0.003
Particulate	0.15	0.01
CO2	1000	450

Average Emission Rates
Clear Skies

	Coal g/kwhr	Gas g/kwhr
NO_x	0.2	0.06
SO_2	0.3	0.003
Particulate	0.08	0.01
CO_2	900	450

Average Emission Rates
Long Term

ALSTOM

	Coal g/kwhr	Gas g/kwhr
NOx	0.05	0.03
SO2	0.03	0.003
Particulate	0.04	0.01
CO2	90	45

Fluidized Bed Systems

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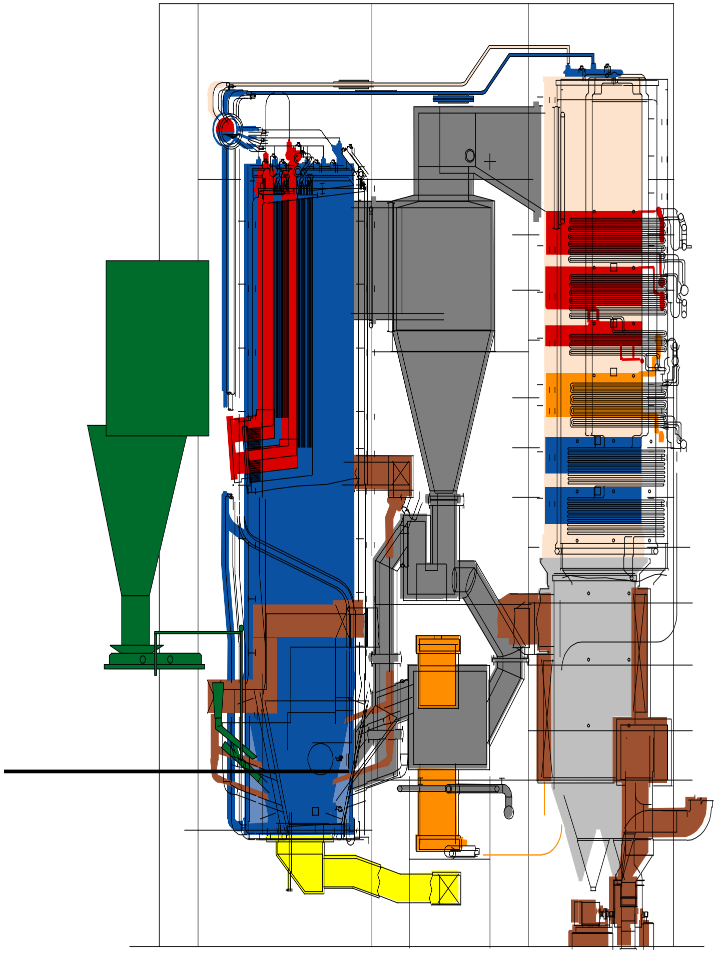
- Reduce Costs (new designs)
- Ultra Clean (integrated APC)
- Grow in Size
  (up to 600 MW USC)
- Enable Re - Powering
- Enable CO_2 capture from combustion based power generation



FDA Process: Dry Injection FGD

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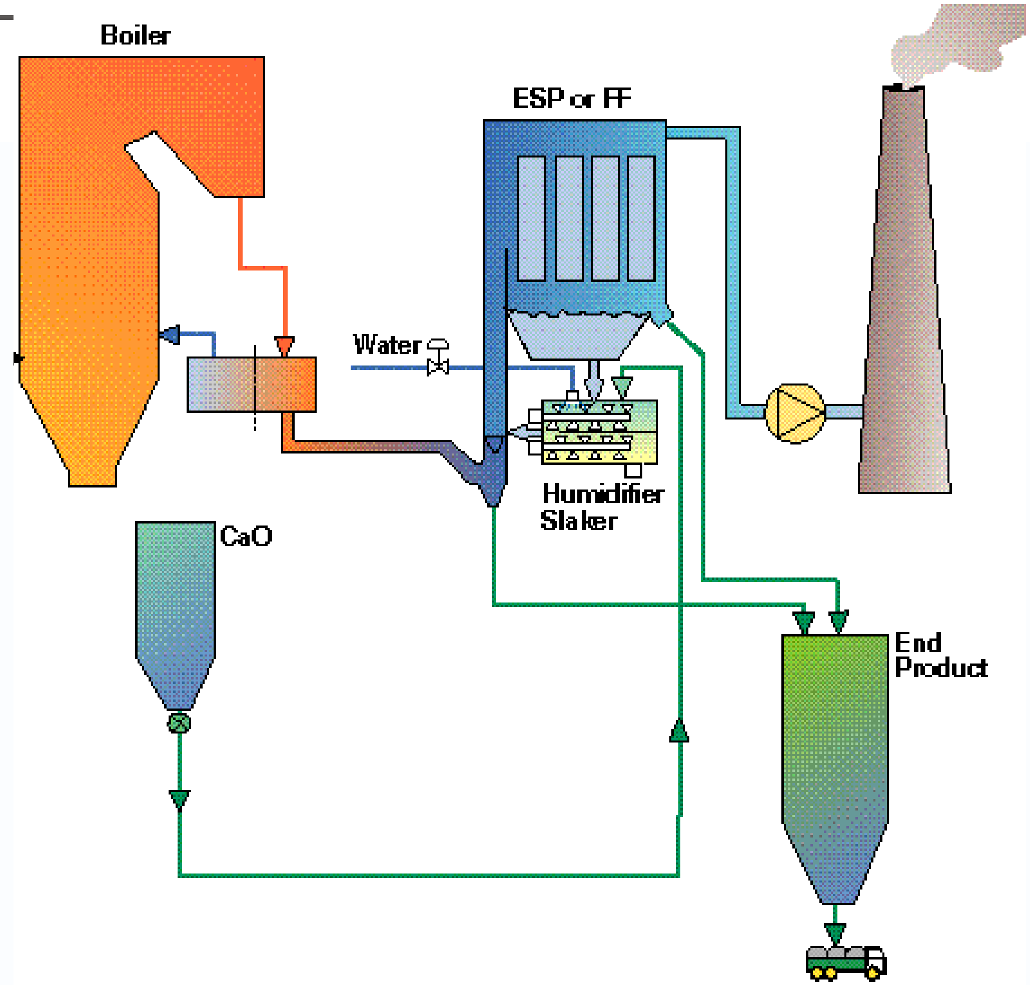
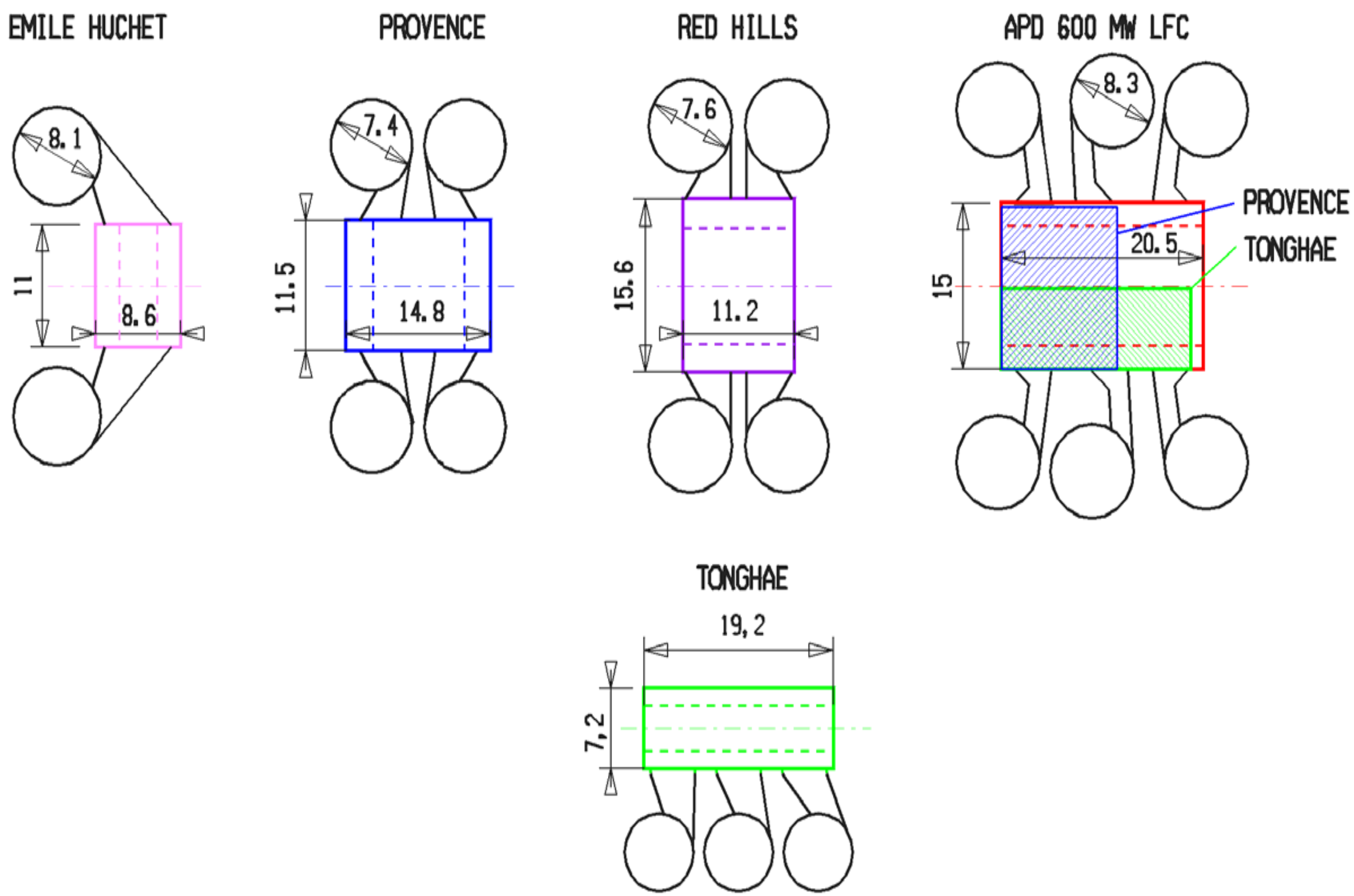
- Dry Injection Process Utilizing
- Enhanced Reagent
- Performance equal to DFGD
- Completed a total of 400 MW installation



95%+ SO_2 Removal

CFB Process Scale-up :Furnace and cyclones



600 MW SC CFB BOILER

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OBJECTIVES

Develop a CFB boiler able to compete economically with PC boilers in the range of 600 MW while taking advantage of CFB's environmental performances and flexibility.

MAIN CHALLENGES

- Scale-up CFB size from existing 250 MW units up to 600 MW
- Accommodate CFB process and once through supercritical constraints:
  - tube protection against overheating
  - heat transfer surfaces distribution
- Accommodate high steam conditionss: 3958 PSI/1112°F/1112°F
- Low emission levels:

Low emission levels:	SO_2	200mg/Nm^3 (0.16 Lb/MM BTU)
	NO_X	200mg/Nm^3 (0.16 Lb/MM BTU)
	CO	100mg/Nm^3 (0.08 Lb/MM BTU)

600 MW CFB BOILER
General Arrangement

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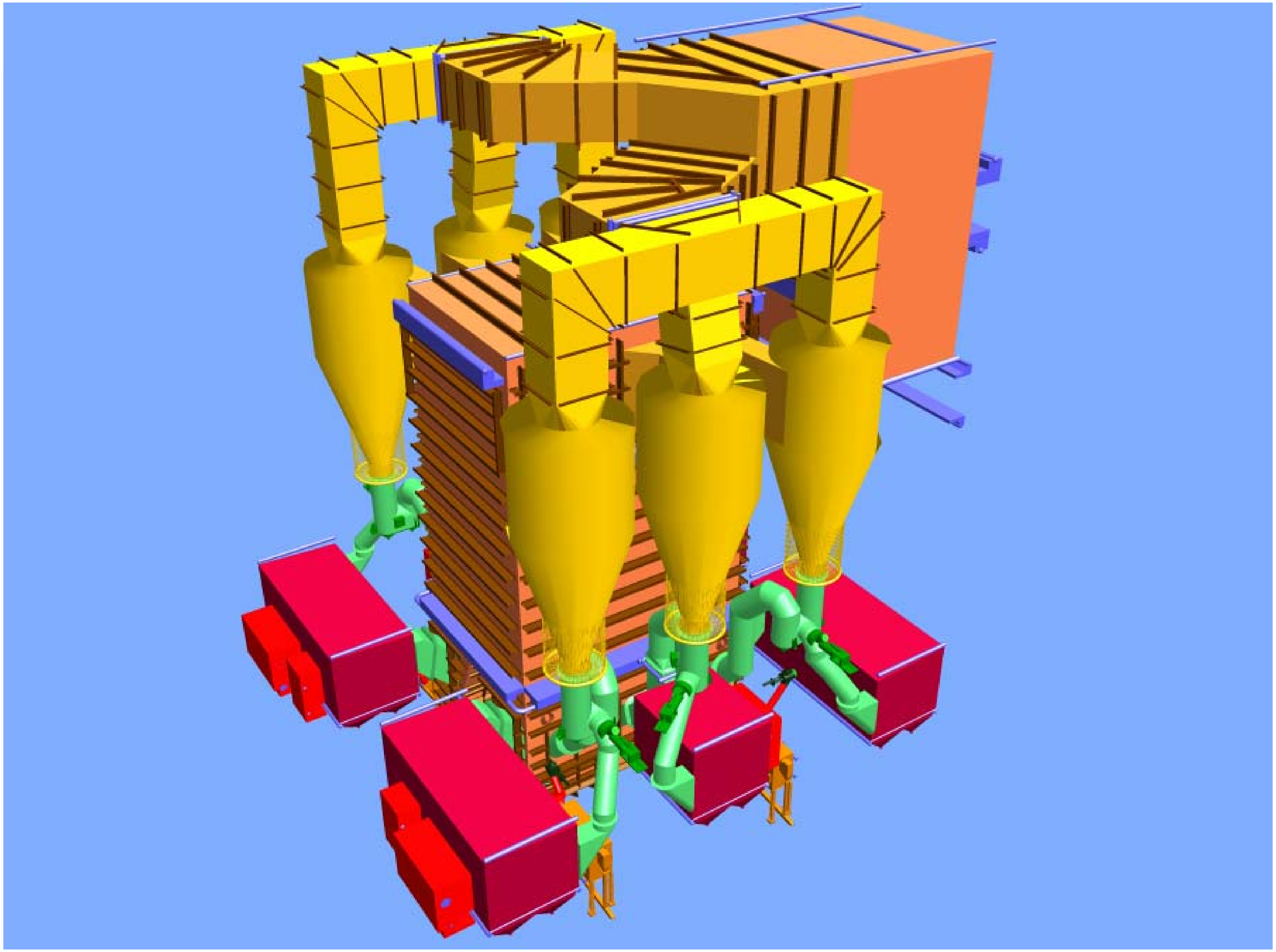

Circulating Moving Bed

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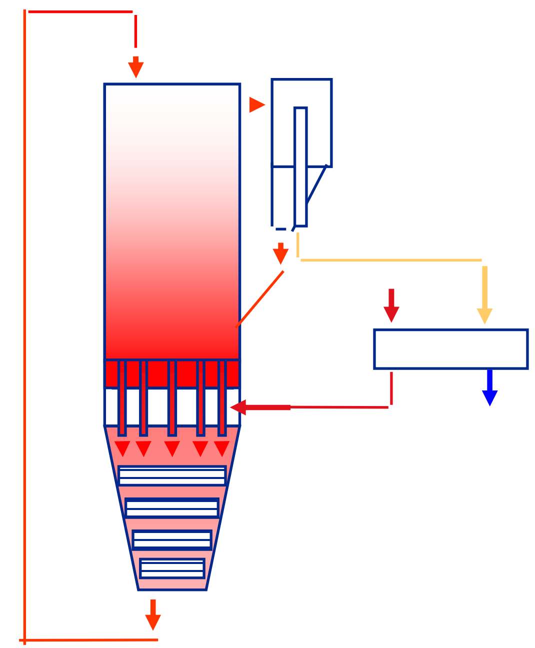
- Separate heat transfer from combustion.
- Potential 30% cost savings in the boiler island
- More effective surface allows higher steam conditions at lower cost
- 15% Lower auxiliary power
- Lower emissions
- 3 - 5 years time frame



Circulating Moving Bed

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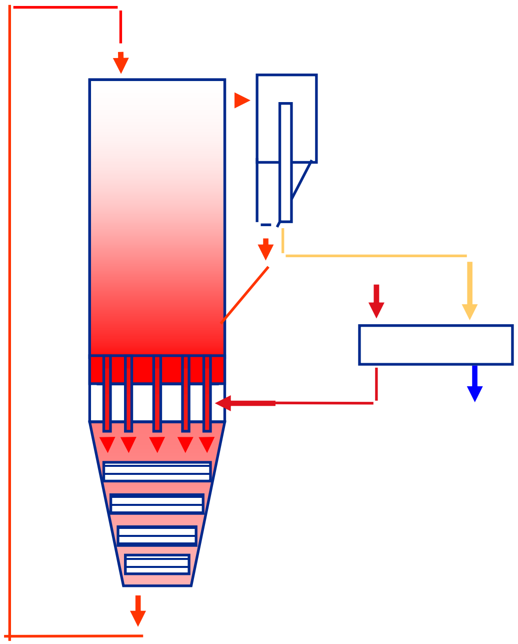
- DOE Contract for pilot testing.
- Heat transfer tests verify potential 30% cost savings in the boiler island
- High temperature tests show no evidence of plugging or sticky ash
- Moving bed heat exchanger demonstrated.
- Will need field demonstration to prove solids distribution in large units



CO2 Capture Options

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1) "Tail-end" CO_2 capture

- adsorption/stripping process (MEA,MEA/MDEA, physical absorbents)

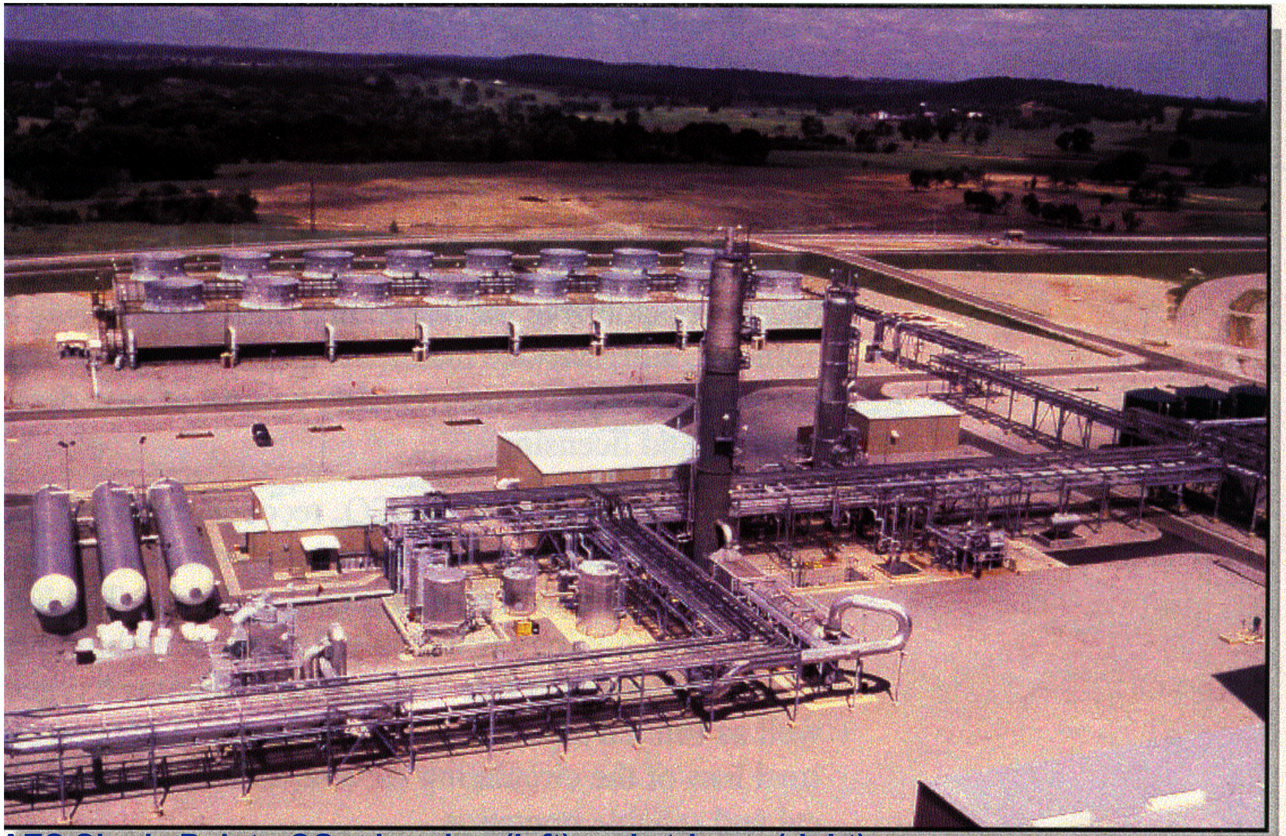
2) Oxygen combustion

- internal (membrane) or external (ASU) O_2

3) Other options

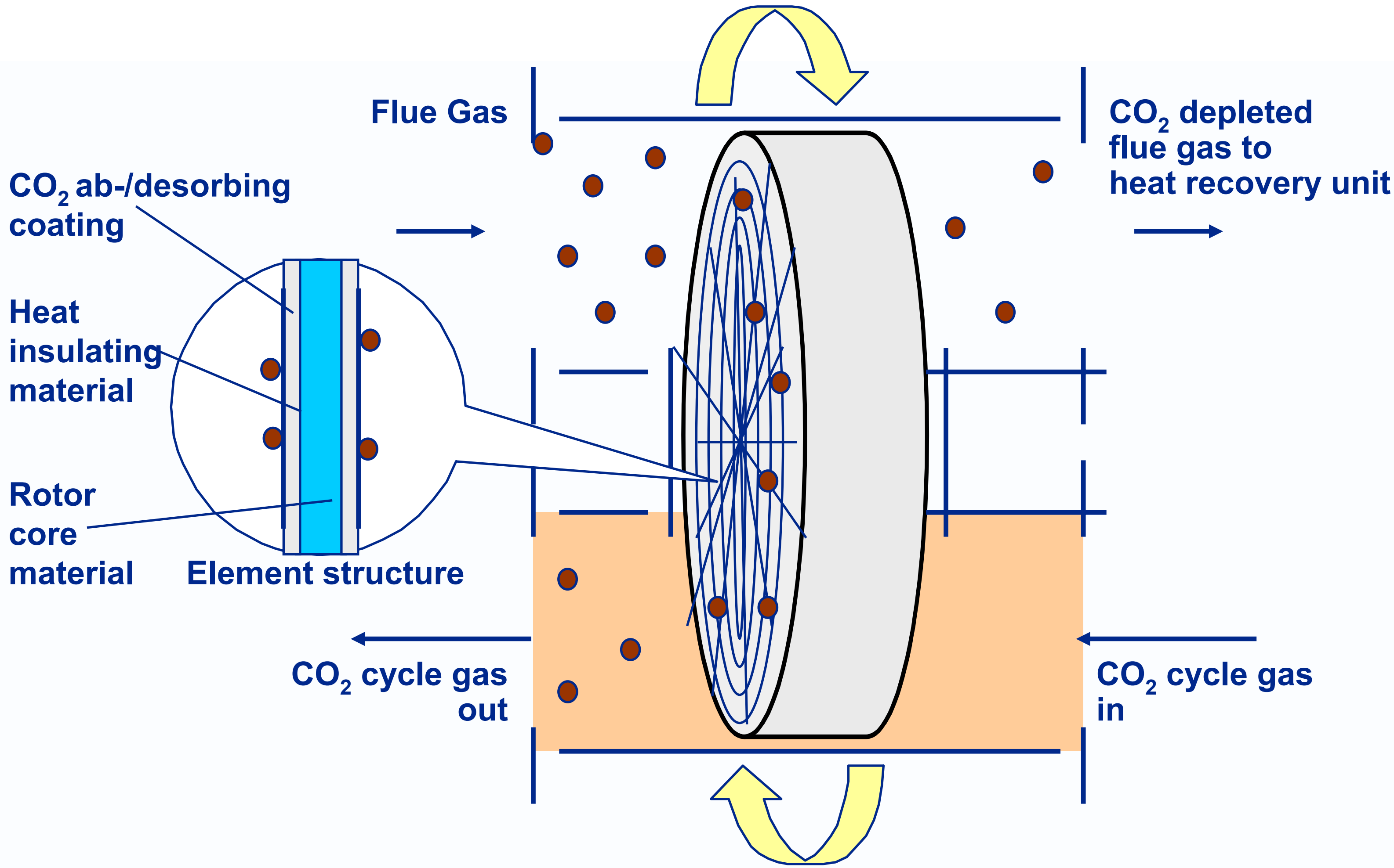
- oxidation/reduction cycles
- carbonate capture
- chemical looping
- syngas decarbonization

Innovative technology options just now emerging



AES Shady Point - CO_2 absorber (left) and stripper (right)

CO_2 Capturing Mechanism and Element Structure



DOE Greenhouse Gas Management Oxygen Fired CFB

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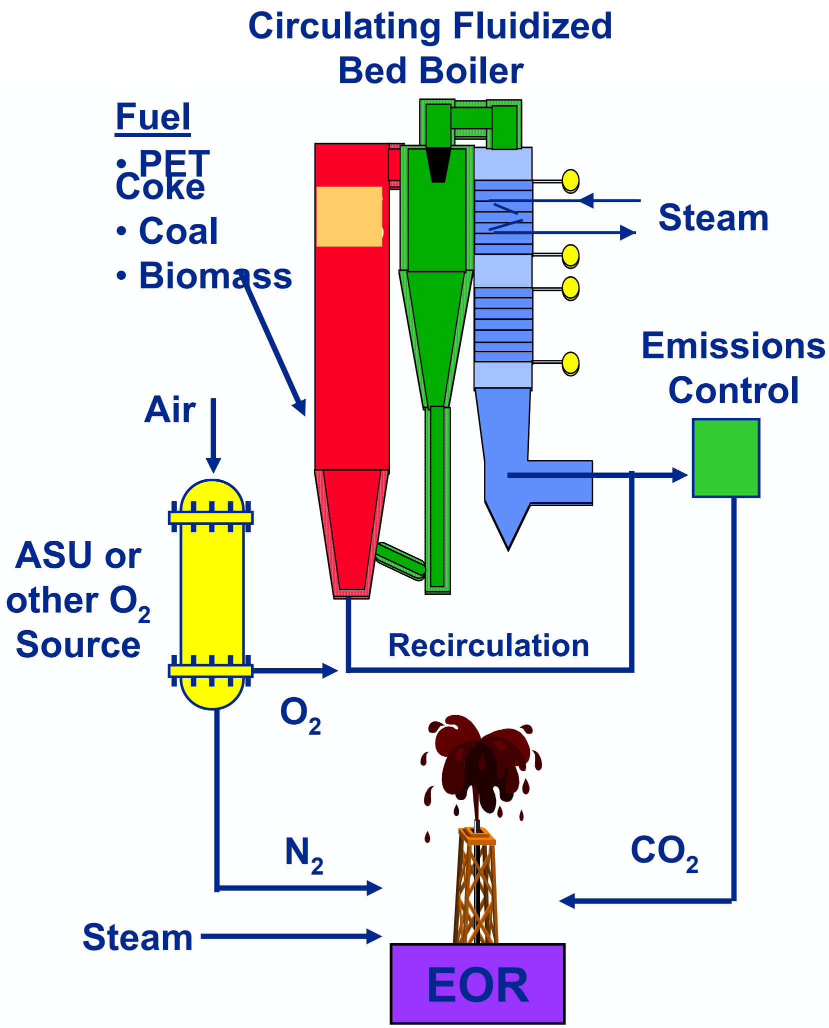
- Can use multiple fuels
  - coal, petcoke, biomass
  - opportunity fuels, tar sands
- Use circulating solids to control furnace temperature
- Retrofitable
- Opportunities to make significant size (=$) reductions in greenfield design
- Existing/expanding market for EOR



Adv. FB with CO2 Capture

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Advantages:

- Produces a slipstream with > 95% CO_2
- Approx 80% capture of CO_2
- Air blown -- No O_2 feed
- No energy penalty before CO_2 liquefaction
- Sorbent lost to the CO_2 cycle is usable by FDA for SO_2 capture
- A CFB system could capture 30 - 40% of CO_2. This could be used as a more near term solution.
  - CFB in 4 - 5 years
  - Adv.FB in 5 - 8 years

Advanced Fluidized Bed

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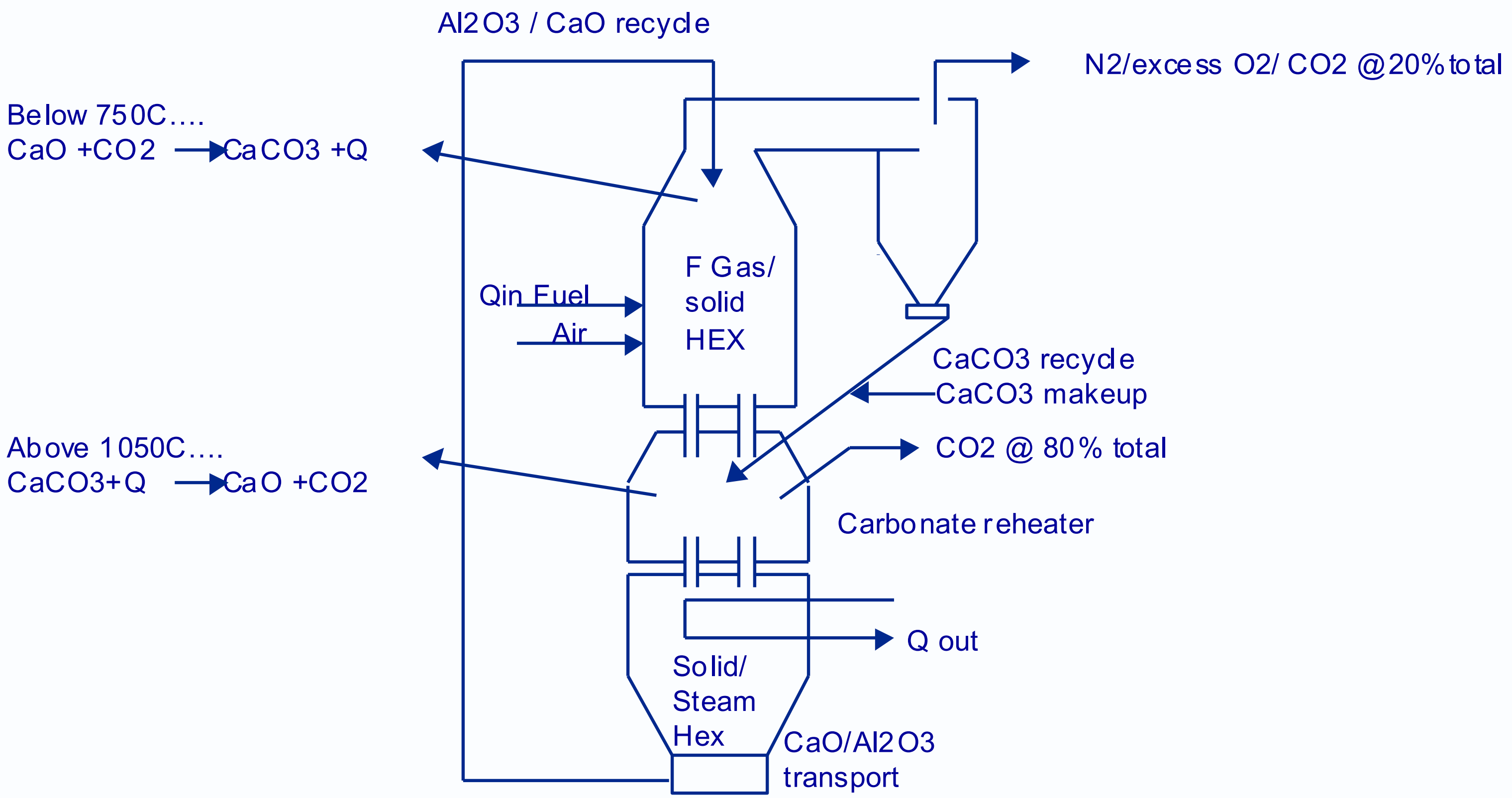
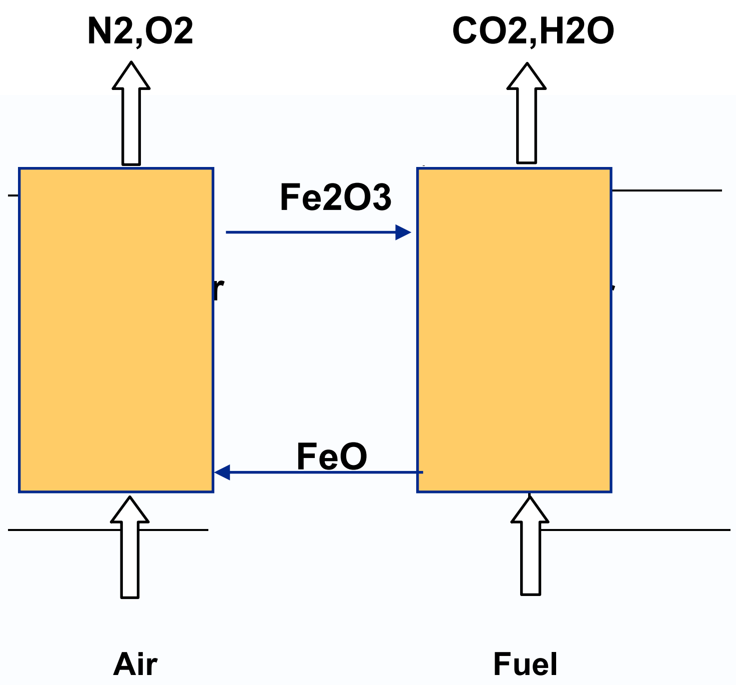
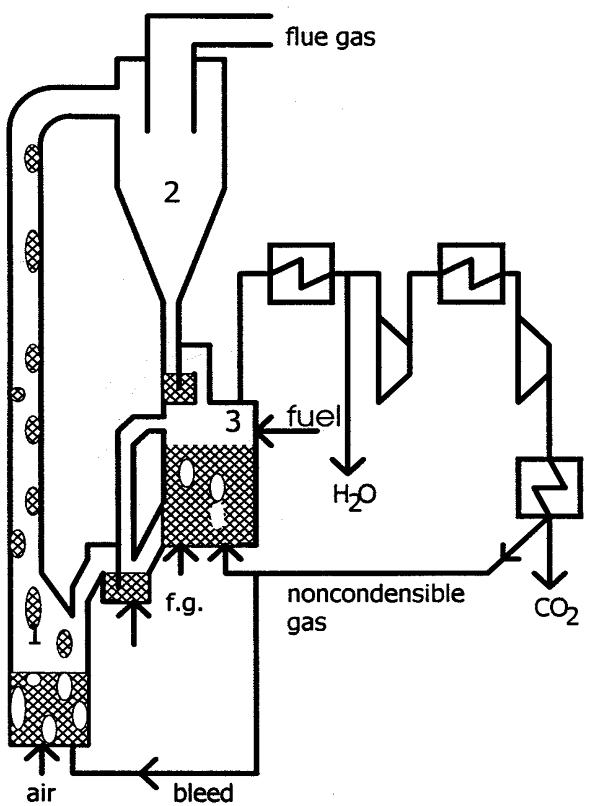
CO2 capture via chemical looping

Power
Technology



Indirect Combustion





- Atmospheric Pressure
- Oxygen carriers (Cu, Cd, Ni, Mn, Fe, Co)
- Potential combustion process with interconnected FBC's

[Ref. Lyngfelt & Leckner]

Advanced Chemical Looping

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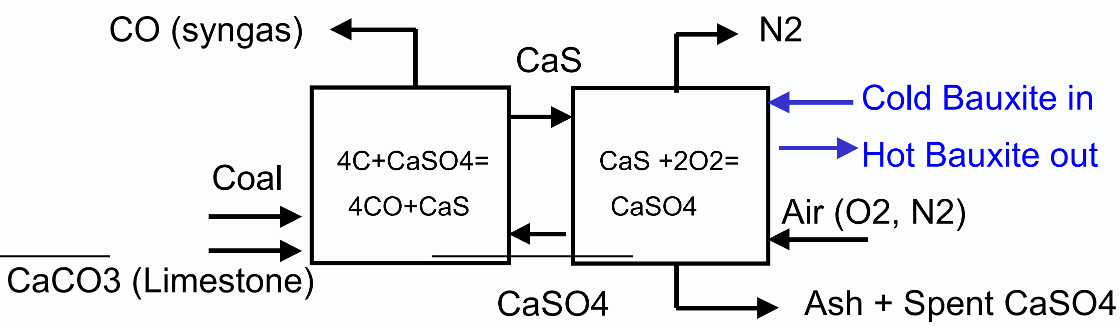

CaS to CaSO4 chemical loop

Advanced Chemical Looping

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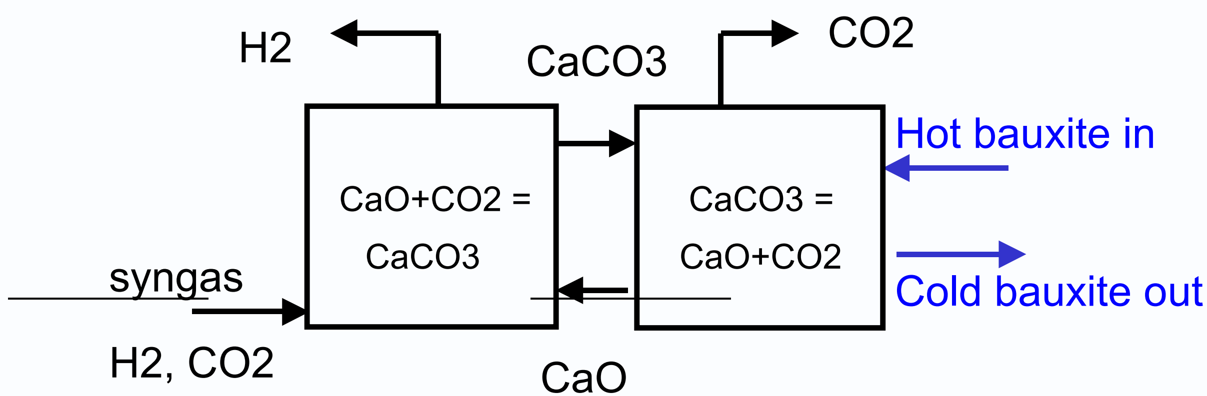

CaO to CaCO3 Chemical loop

Performance Comparison

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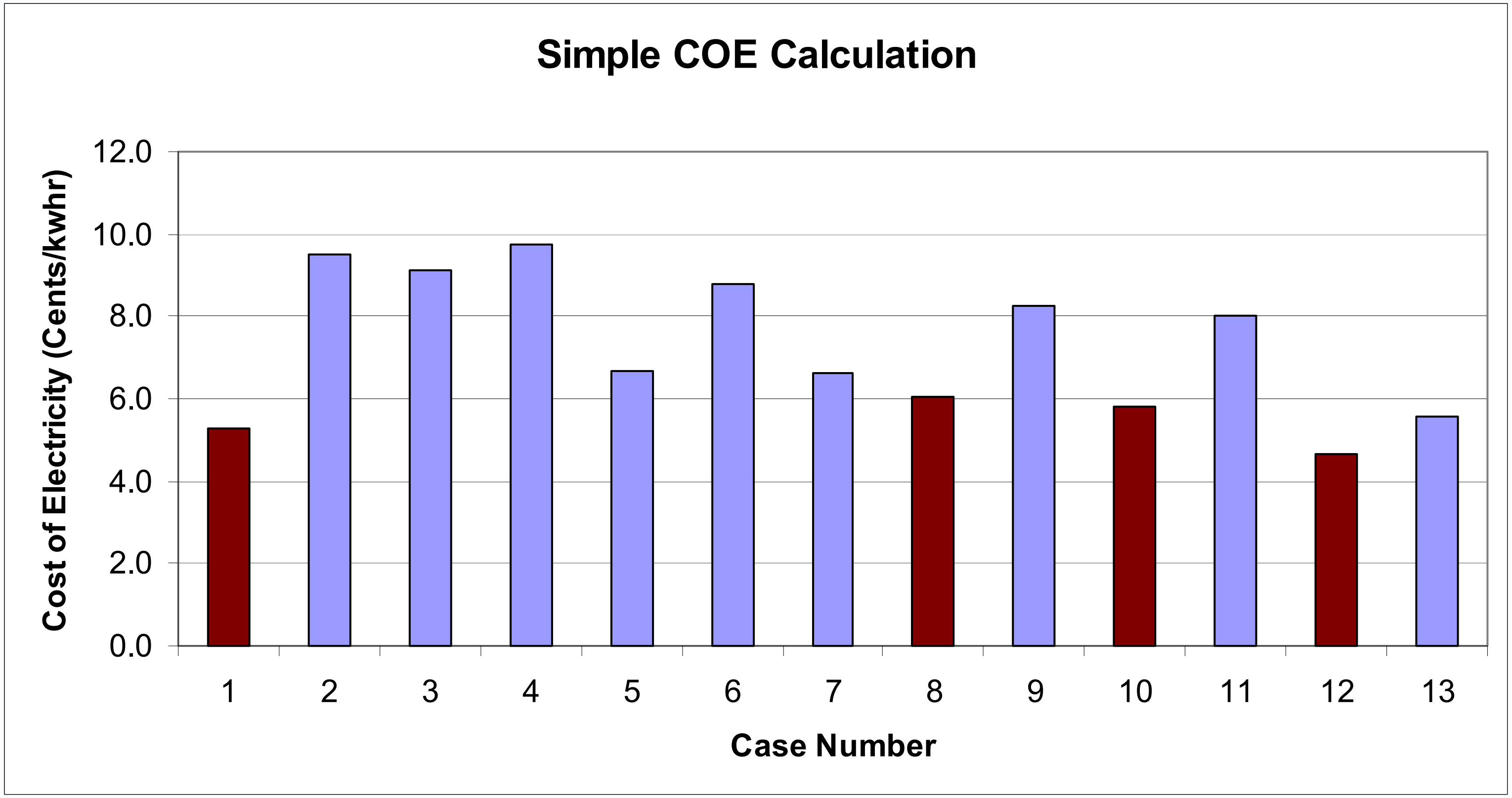
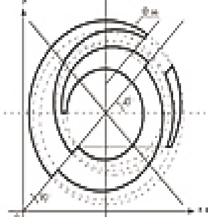
	NGCC " H" class machine	Ultra supercritical PC	Thermie PC Normalized	IGCC cold gas clean-up H machine	Chemical looping H class cold clean	Chemical looping + SOFC
Cycle	Combined	Rankine	Rankine	combined	combined	SOFC+HRSG
Fuel	gas	coal	coal	coal	coal	coal
SH bar	124	345	375	125	123	165
SH C	565	649	700	538	568	538
1 stRH C	565	649	720	538	568	538
2 nd RH C		649	720			
GT inlet C	1427			1427	1427	
Aux pwr % gross	1.8	5.50	6.60	10.40	7.90	14.30
condensor bar	0.07	0.07	0.07	0.07	0.07	0.07
stack temp	86	146	138	132	135	130
HHV efficncy -no CO2	53.5	42.7	46.10	43.1	48.9	
LHV efficiency -no CO2	59.5	45.4	47.30	45.7	51.2	
kg of CO2/kwh no CO2	0.32	0.71	0.66	0.7	0.62	
HHV efficncy -with CO2	43.3	31.0	34.4	37.0	41.3	59.3
kg of CO2/kwh with CO2	0.044	0.104	0.091	0.086	0.077	0.054
source	EPRI Parsons	EPRI Parsons	Alstom normalized to Parsons	EPRI Parsons	premlinary Alstom Andrus	premliminary Alstom Andrus

coal power is a real option

Preliminary COE Comparison

- Advanced Chemical Looping Plants show promise for capturing CO_2, meeting all other environmental requirements, improving efficiency, and being cost effective.





CO2 Summary

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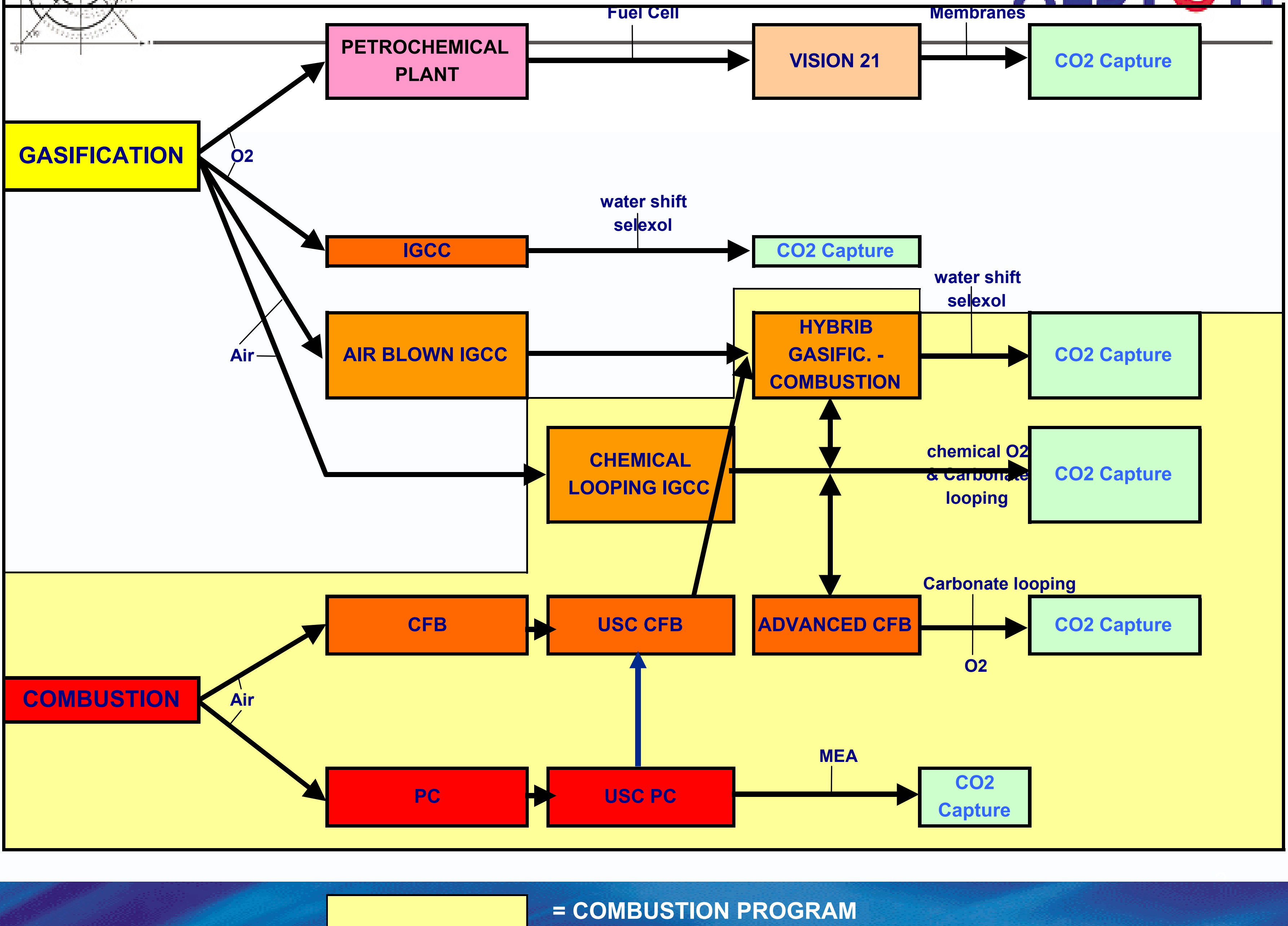
Process	Technical Status	Cost	CO2 Reduction	CO2 Quality
Amine Scrubbing	Proven	Highest	90%	Food Grade
Oxygen Firing	Feasible	High (*)	100%	EOR
CO2 Wheel	New/Bench	Target (?)	50%	High
AFB/CO2	New/Paper	Target (?)	80%	High
Indirect Combustion	New/Bench	Moderate	90%	High
Chemical Looping	New/Bench	Moderate	90%	High
IGCC w/CO2	Proven	High	90%	Food Grade
Advanced Chemical Looping	New/Paper	Target	90%	High

Coal Power Plants
A Portfolio of Alternate Paths



Zero Emissions Gas Plant

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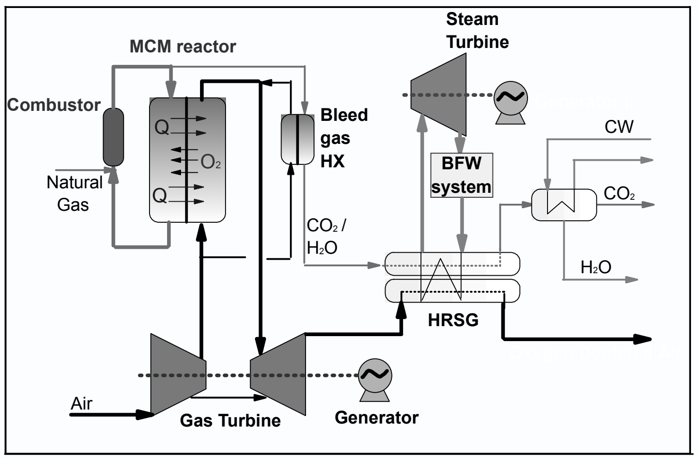
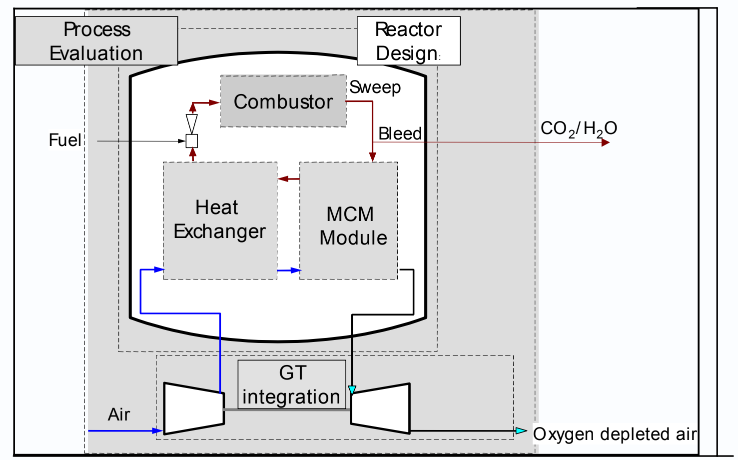
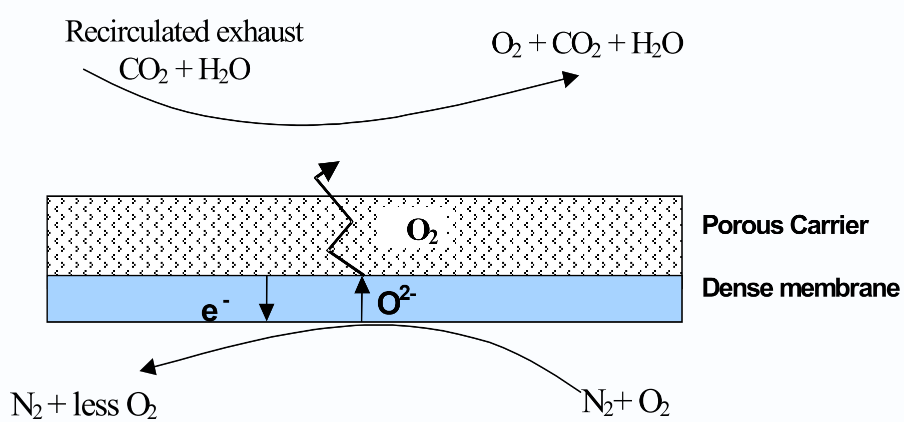
- AZEP uses membrane technology to separate oxygen from air.





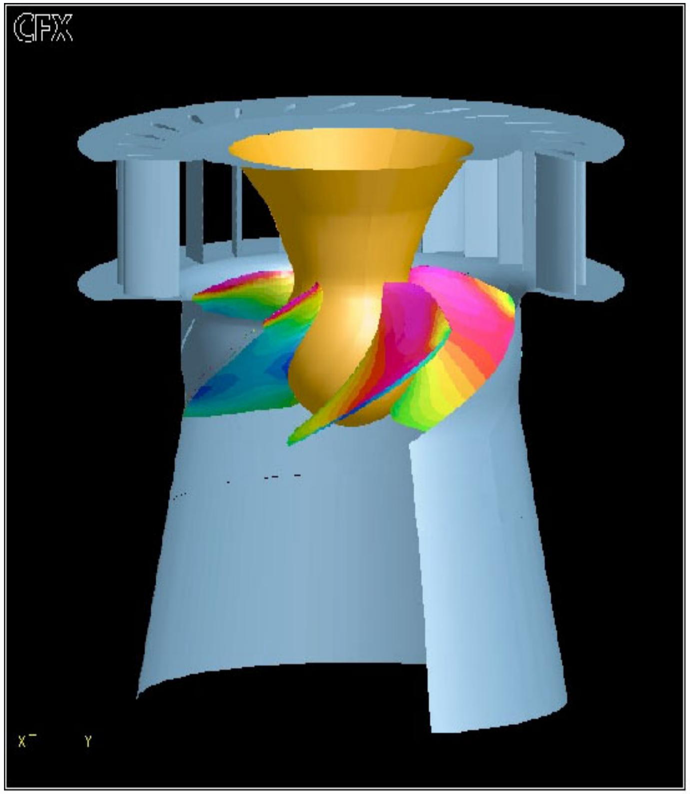


Turbine Technology

ALSTOM

New product : Green turbine

- Environment a real concern for ALSTOM :
  - Development of fish friendly turbine
  - Introduction of dissolving oxygen
  - Use of greaseless components
- Alstom active in industry groups addressing these issues:
  - DOE Advanced Hydro Power Turbine Program
  - Professional organizations like NHA R&D and Hydrovision



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