

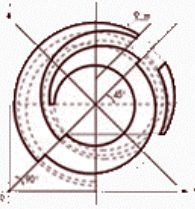
July 06

ALSTOM

## CO<sub>2</sub> and CLEAN COMBUSTION

ALSTOM the Clean Combustion Specialist

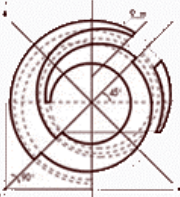
ALSTOM



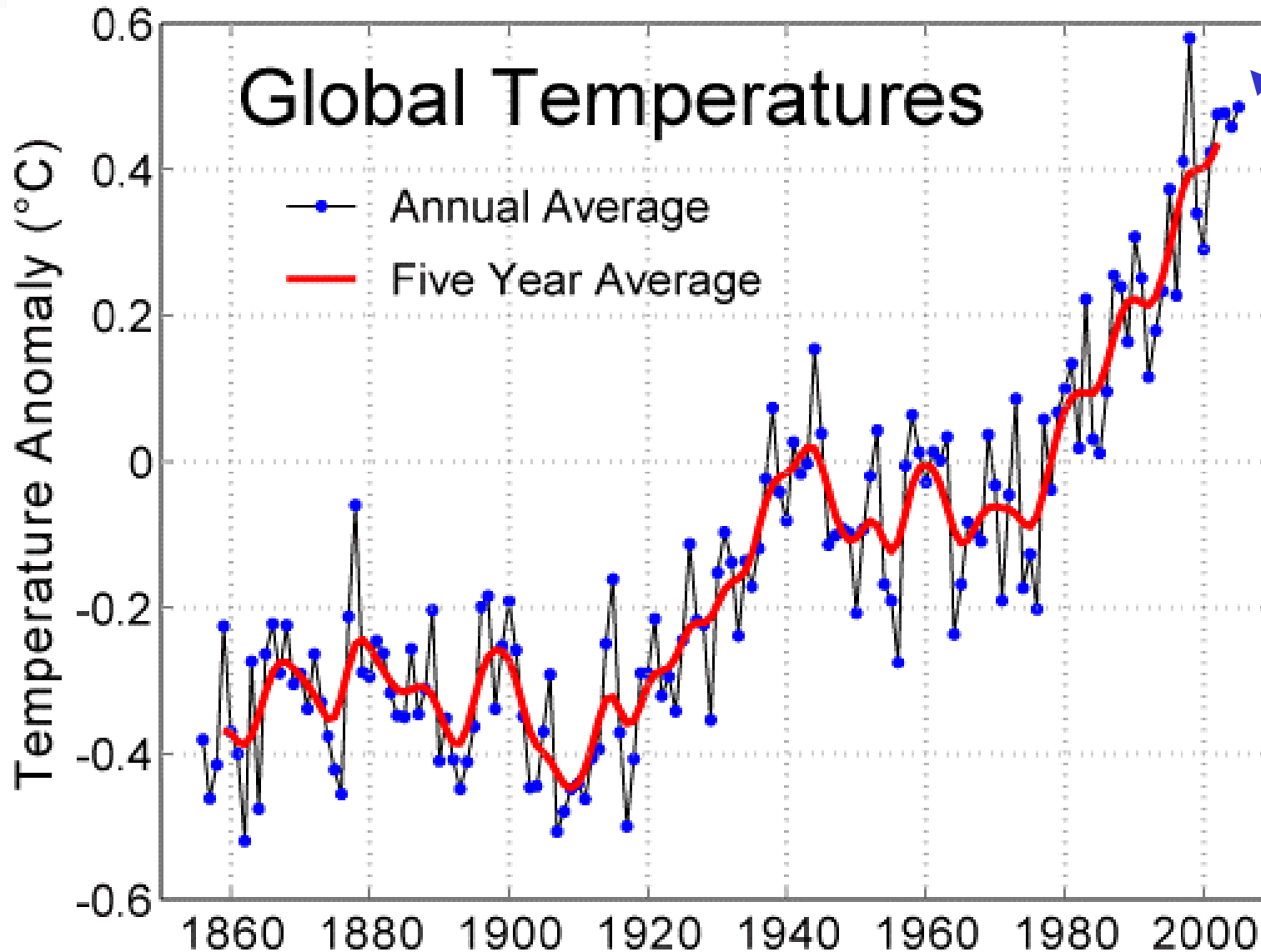
# CO2 and Clean Combustion



- The challenge of the greenhouse effect in 4 slides...
- Emitters and commitments...
- Our customer's questions and the ALSTOM overall product offering
- Clean combustion explained
- Alstom R&D strategy and vision of future technology portfolio
- Costs of capture options compared
- Status of R&D and partnerships



# Temperature evolution in the industrial age...



1998, 2005 are the warmest years ever recorded!

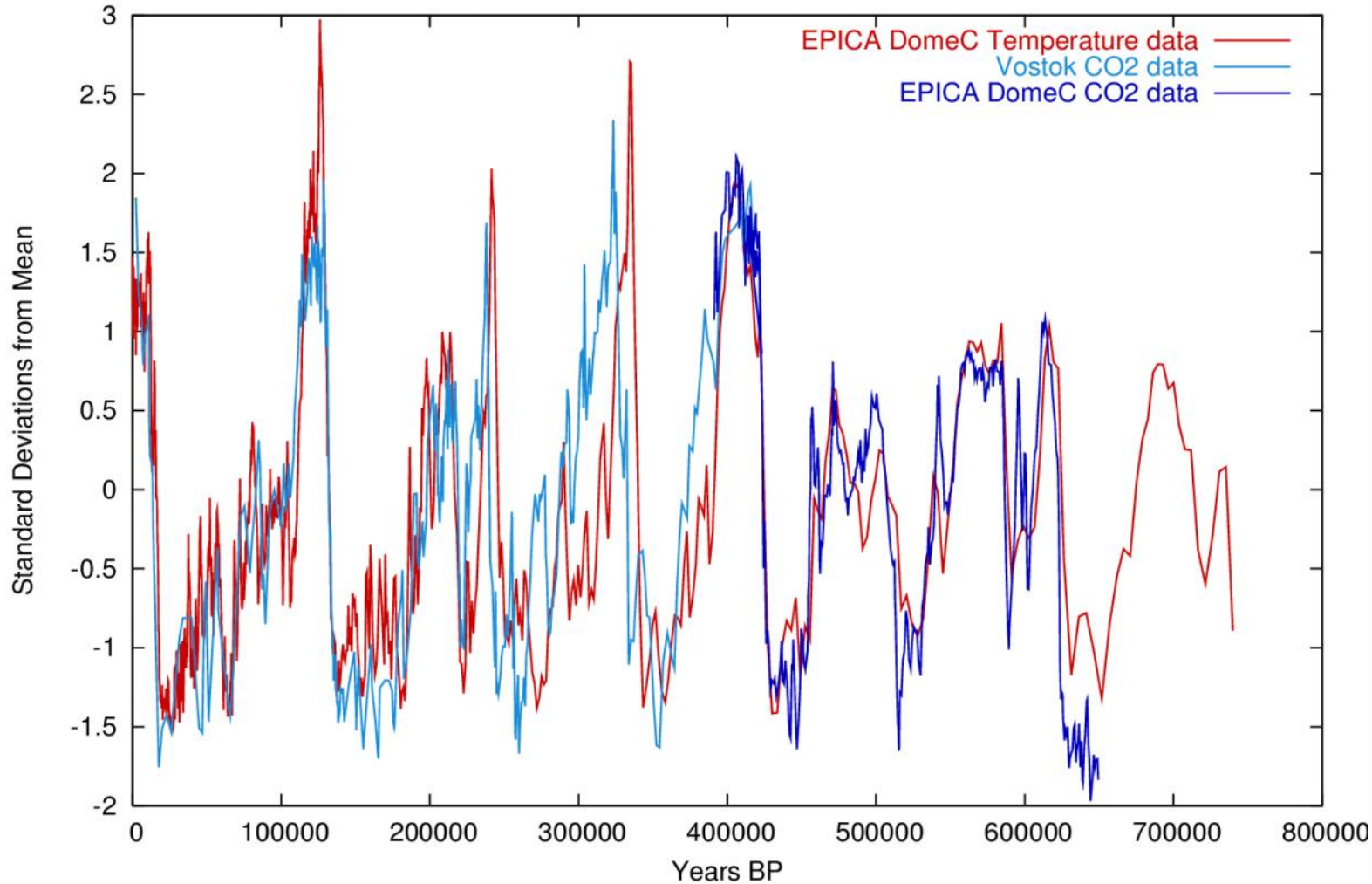
2002, 2003 and 2004 are close seconds...

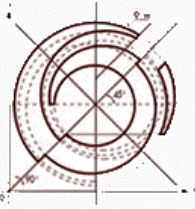


# Temperature and CO2 are correlated



## CO2 and Temperature Records





# Depletion of summer sea ice

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High latitude systems are vulnerable, especially Arctic...

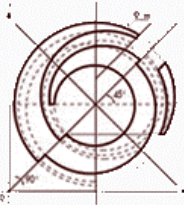
REF: ACIA, Impacts of a Warming Arctic, Climate Impact Assessment Report, 2004



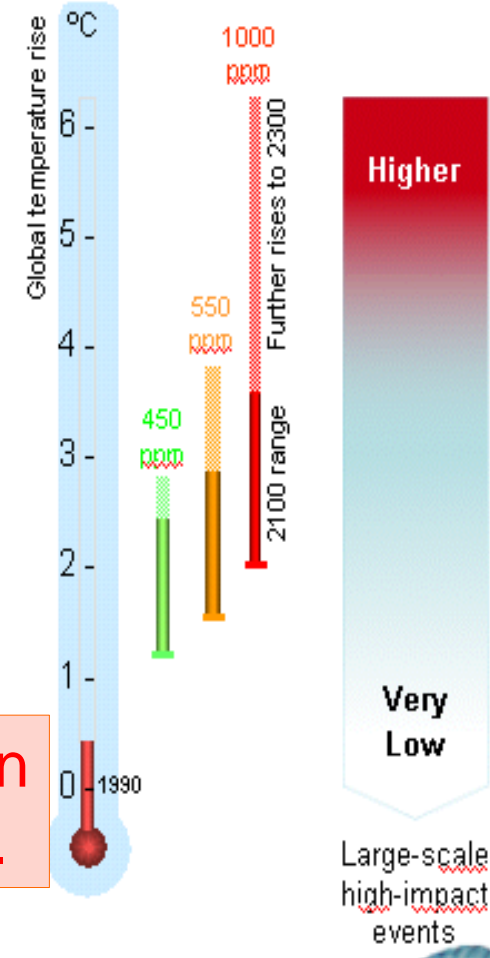
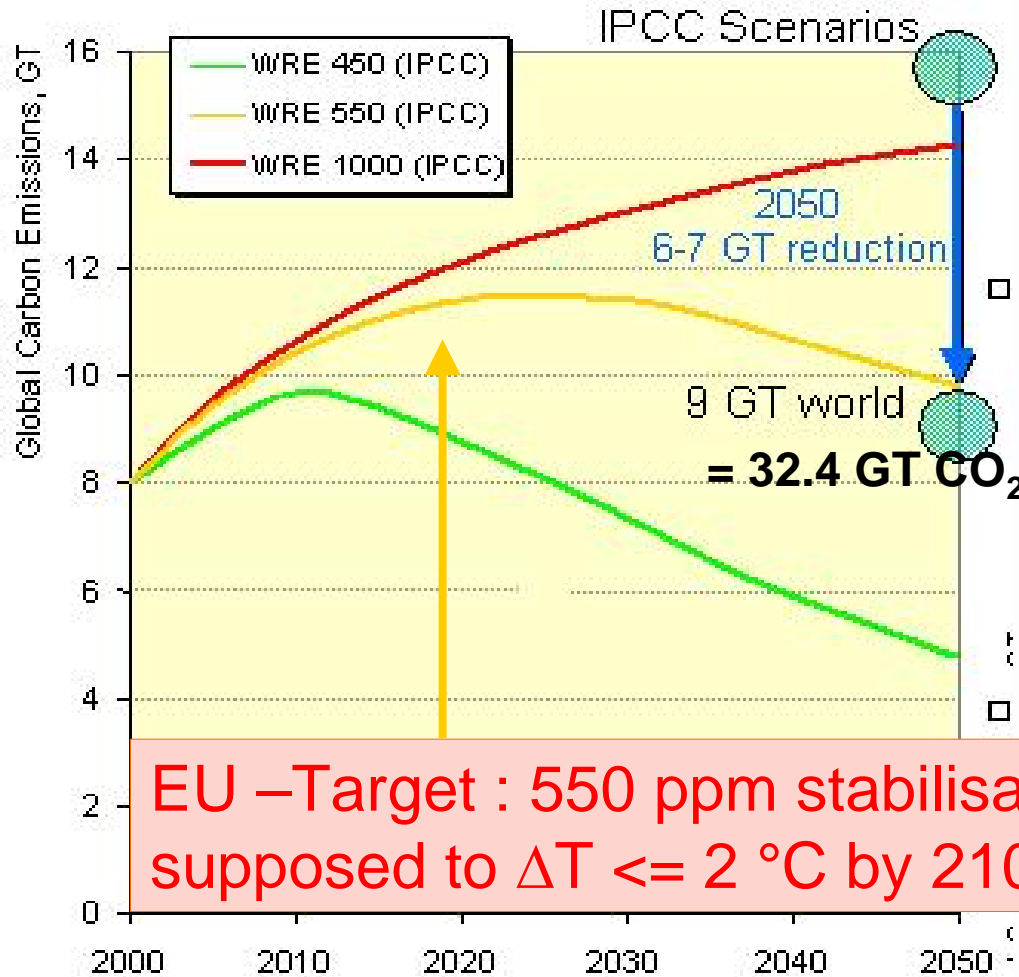
September 1979

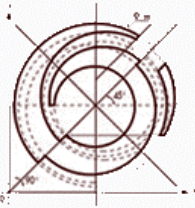


September 2003

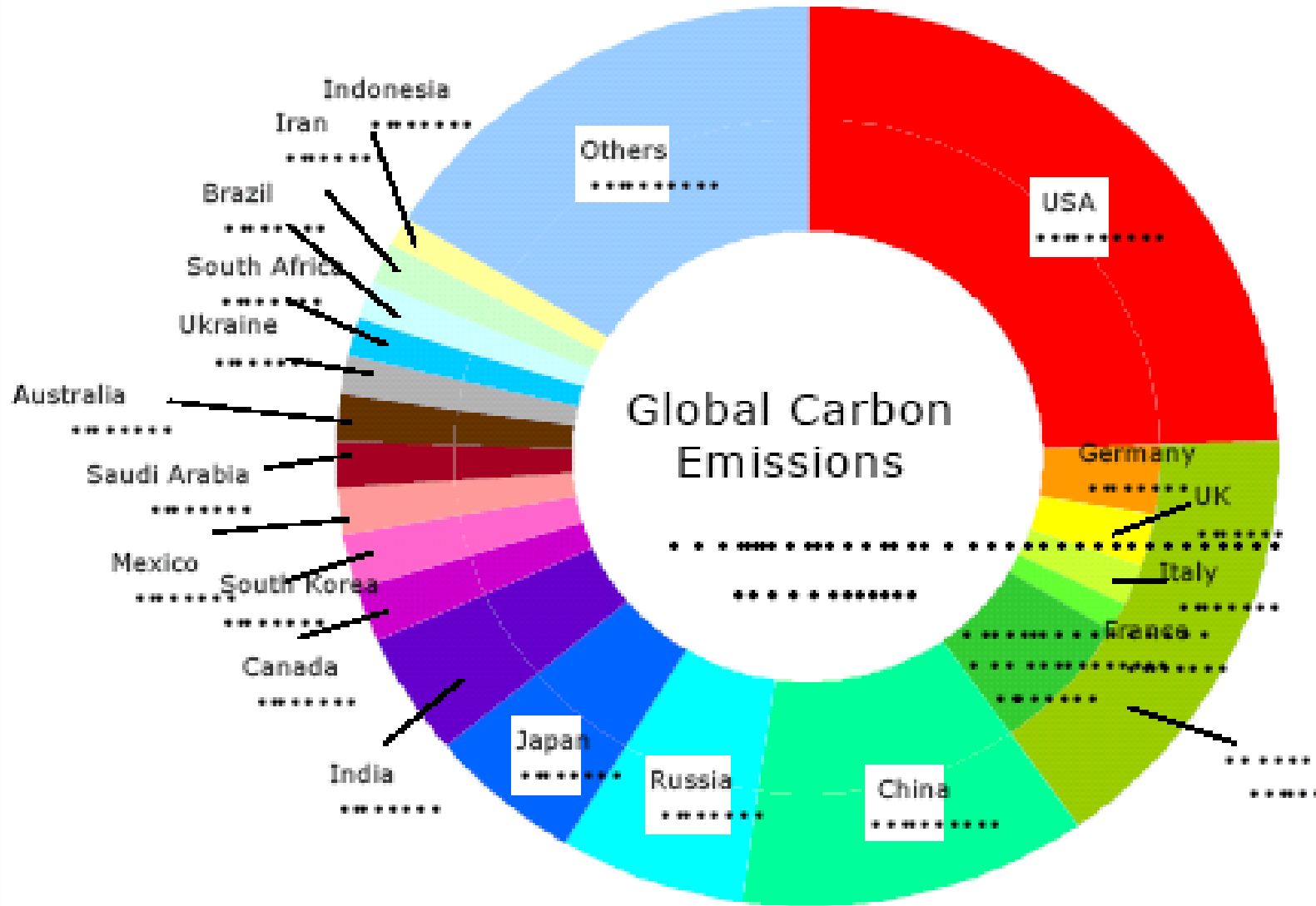


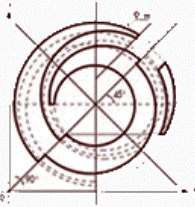
# IPCC Emission Pathways and corresponding Global temperature rise





# CO<sub>2</sub> emissions: who? 1/2

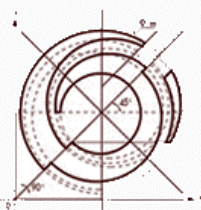




## CO<sub>2</sub> emissions: who? 2/2



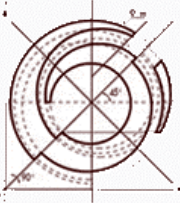
		Emissions (million tons of CO <sub>2</sub> )	Share	Per capita emissions (tons of CO <sub>2</sub> /person)
1	USA	5,605	24.4%	19.86
2	EU 25 countries	3,644	15.8%	8.06
	Germany	786	3.4%	9.57
	UK	568	2.5%	9.50
	Italy	428	1.9%	7.41
	France	362	1.6%	6.16
	Other EU members	1,500	6.5%	7.75
3	China	2,792	12.1%	2.20
4	Russia	1,436	6.2%	9.86
5	Japan	1,185	5.2%	9.35
6	India	1,071	4.7%	1.06
7	Canada	436	1.9%	14.19
8	South Korea	427	1.9%	9.06
9	Mexico	424	1.8%	4.36
10	Saudi Arabia	374	1.6%	17.49
11	Australia	345	1.5%	18.00
12	Ukraine	343	1.5%	6.93
13	South Africa	327	1.4%	7.48
14	Brazil	307	1.3%	1.83
15	Iran	310	1.4%	4.88
16	Indonesia	269	1.2%	1.28
	Others	3,706	16.1%	--
	World total	23,001	100.0%	3.80



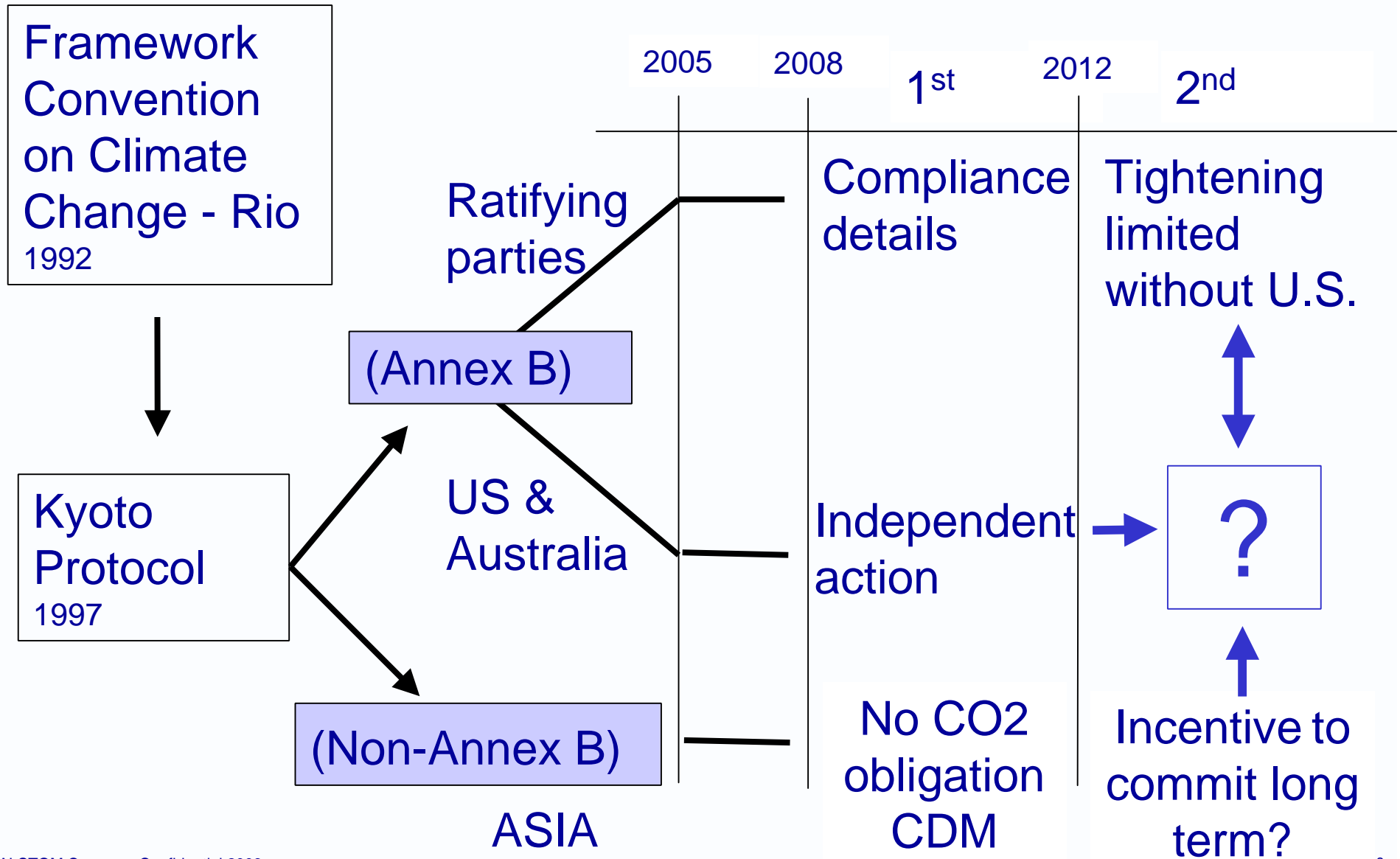
## Overview of contributions so far

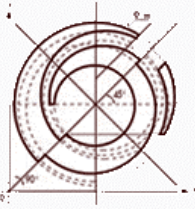


- USA: decided in 2001 not to ratify the protocol, but should have achieved a 7% reduction by 2012 compared to 1990 levels
- Australia: rejected Kyoto but would have been allowed an 8% increase by 2012 compared to 1990 levels
- Canada: 6% total reduction by 2012 compared to 1990 levels
- Europe: 8% total reduction by 2012 compared to 1990 levels
- Japan: 6% total reduction by 2012 compared to 1990 levels
- Russia/Ukraine: no obligated reduction – long on CO2 compared to 1990 levels
- Asia: no commitment, but eligible to CDM and technology transfers



# Process evolution: an uncertain future...





## CO<sub>2</sub> is a long term global issue...

**ALSTOM**

- In order to achieve the 550 ppmV stabilisation by 2010, IPCC projections show mean GDP losses in Annex B countries between 0.21% and 1.58%
- 1997 MIT study demonstrates that Non-annex B countries must participate in the CO<sub>2</sub> emission reduction effort to limit the CO<sub>2</sub> to the 550 ppmV goal (\*)
- IPCC projects a global GDP loss of 0.5% to 2% in the year 2050 for the 550 ppmV goal

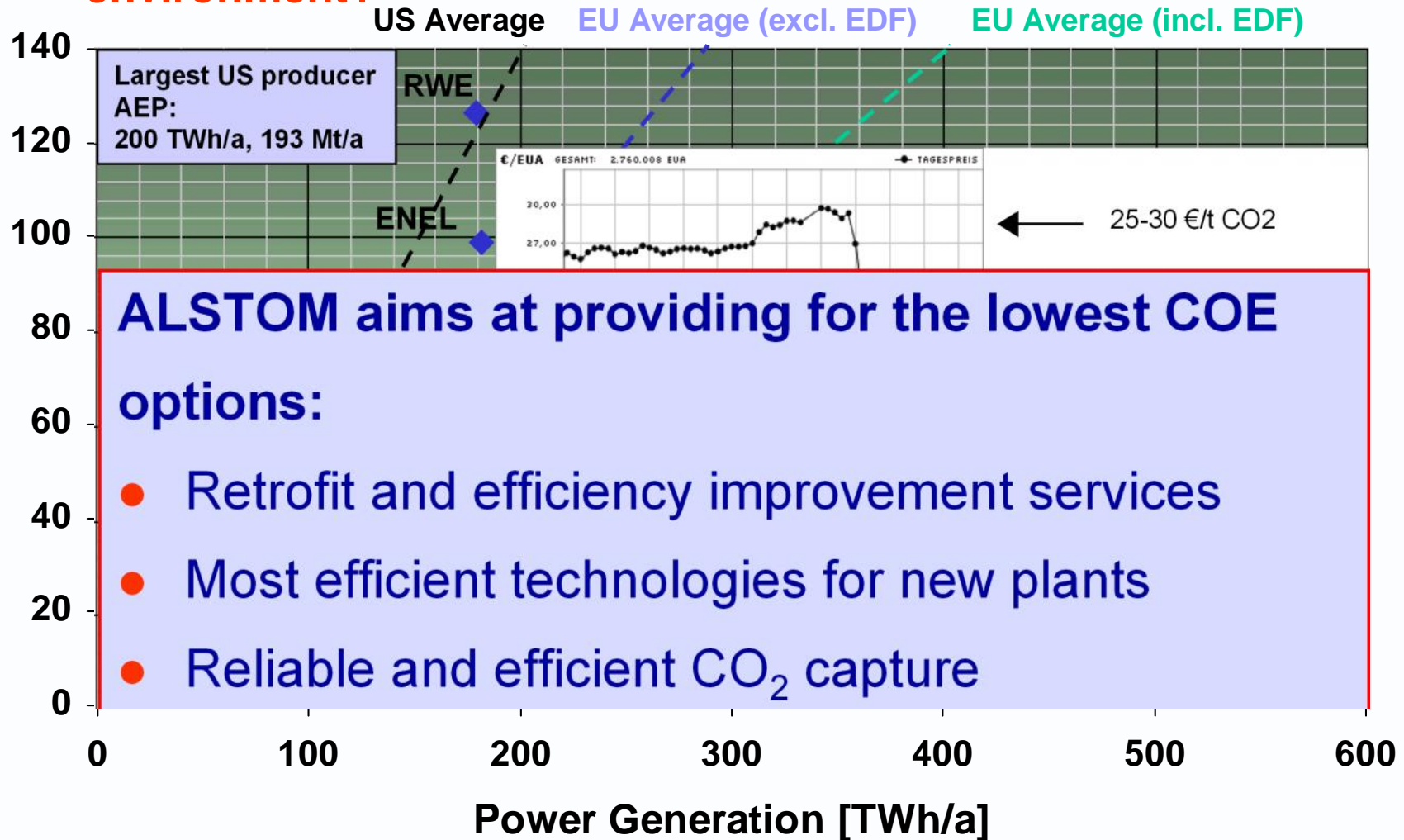
(\*) Necessary conditions for Stabilization Agreements by Zili Yang & Henry D. Jacoby, May 6, 1997



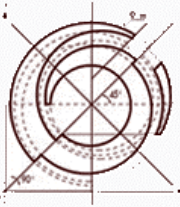
# CO<sub>2</sub>: The situation for the major European power producers



## Which CO<sub>2</sub> Strategy in an uncertain market and regulatory environment?



Source: PricewaterhouseCoopers



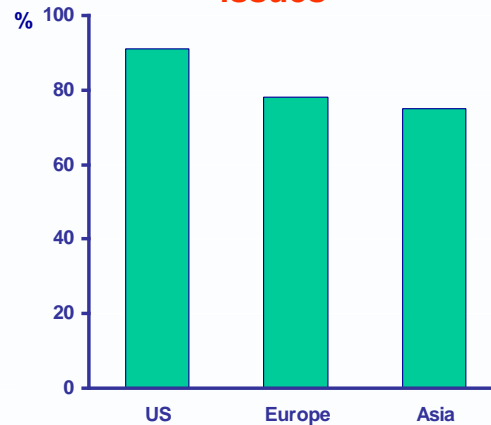
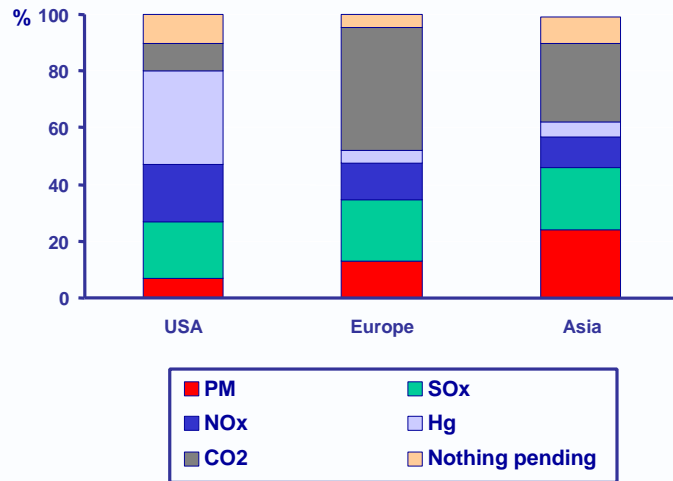
# The voice of our customers:



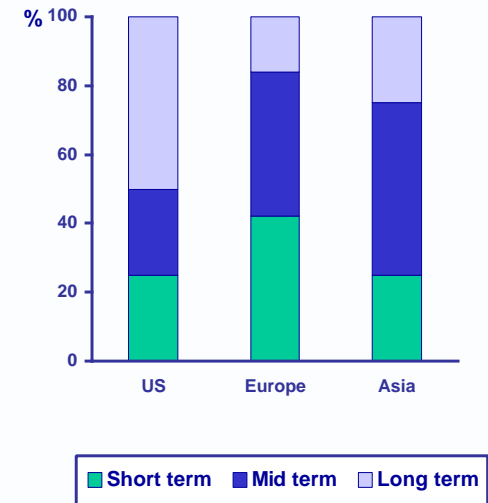
## Clean Combustion Customer perception

"Environmental questions are amongst my top 3 operational issues"

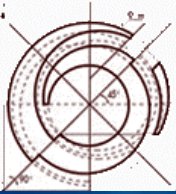
What are your major short-term air pollutant issues?



"In what time horizon do you see CO2 as an issue for you?"



**Environment considered as the main issue**



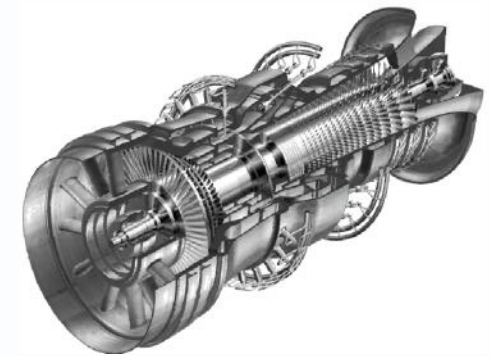
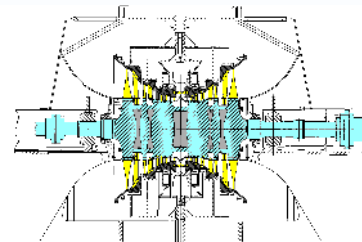
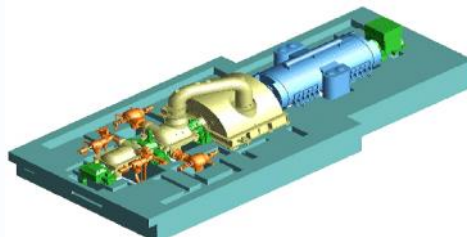
Alstom: an extensive product offering...

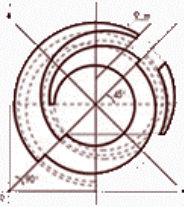
**ALSTOM**



Service  
 Plant Integration  
 New Boilers  
 Boilers Retrofit  
 Heat Recovery  
 Steam Turbines

Hydro  
 EC Systems  
 Generators  
 Large GT  
 ST Retrofit

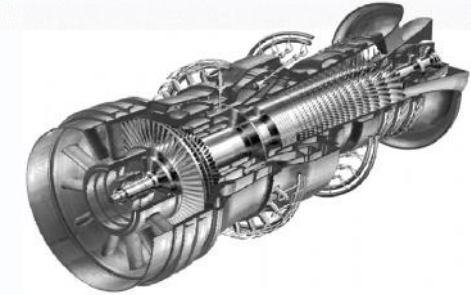
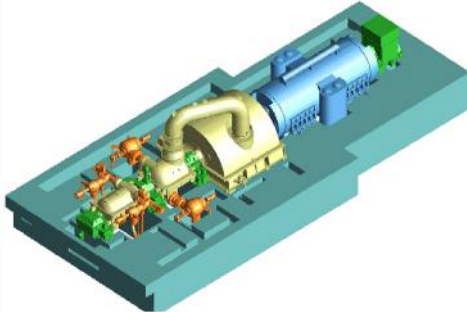




# Turbomachines Portfolio

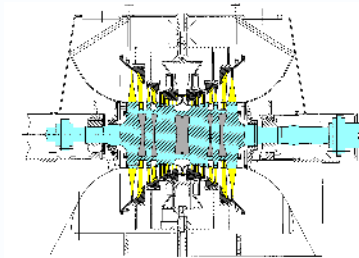
**ALSTOM**

- Low emission Gas Turbines with wide operating flexibility from 50 MW to 281 MW



- High efficiency, modularized Steam Turbines for the entire range from 100 to 1'800 MW

- Market leader for Retrofitting Steam Turbines with over 50% market share – many on 3<sup>rd</sup> party units



- Largest air cooled Turbo-Generators in the market (up to 400 MW) providing lower operating cost
- H<sub>2</sub>/water cooled Generators up to 1'800 MW

**Technology Competence in ALL Turbomachines**



# Energy & Environment Systems Group Product offering

# ALSTOM

## Energy Recovery Systems



A world leading portfolio of product such as air preheaters and gas-to-gas heat exchangers, transfer line exchangers, mills ... both for Power, Industrial and Petrochem applications

## Environmental Control Systems



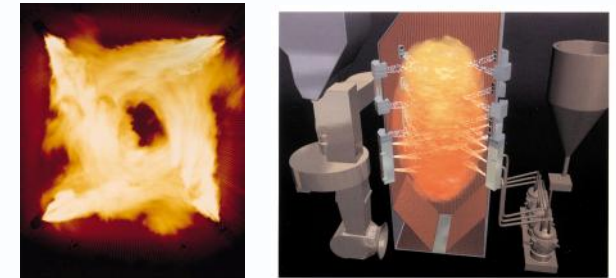
Complete range of proven air pollution control solutions for power and industrial applications for environmental compliance (Sox, Nox, Particulate, Mercury, ...)

## Boilers



Wide range of Clean, Efficient & Reliable Combustion solutions - Pulverised Coal, Circulating Fluidized Bed and, for large gas turbine in combined-cycle applications, Heat Recovery Steam Generator

## Boiler Retrofits



Full scope covering refurbishing & up-grading boilers to improve power plant performance (efficiency, life extension, environmental performance - Low Nox burners- , fuel conversion, pressure part re-design & replacement, ...)

## The broadest Energy and Environmental product range



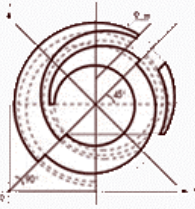
# ALSTOM offer compared...



Product Player	Large GT	Large ST	Boilers	Generators	HRSG	HEX	ECS	Renewable		Nuclear/ Conv. Island	Plant
								Hydro	Others		
ALSTOM	Medium presence	Medium presence	Medium presence	Medium presence	Medium presence	Medium presence	Medium presence	Medium presence	Biomass co-firing	Medium presence	Medium presence
Comp 1	Strong presence	Medium presence	No presence	Medium presence	No presence	No presence	Medium presence	Medium presence	Strong focus on Wind	No presence	No presence
Comp 2	Strong presence	Strong presence	No presence	Strong presence	No presence	Medium presence	No presence	No presence	Strong focus on Wind	Medium presence	Medium presence
Comp 3	Medium presence	Medium presence	Weak presence in CFB	Strong presence	Medium presence	Strong presence	Medium presence	No presence	All renewable energies	Medium presence	Strong presence

**Alstom Ranking**      #3      #1      #1      #1      #2      #1      #1      #1      #1      #1

Strong presence     
  Medium presence     
  No presence

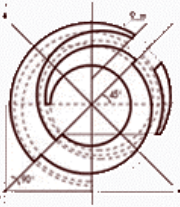


# Clean Combustion

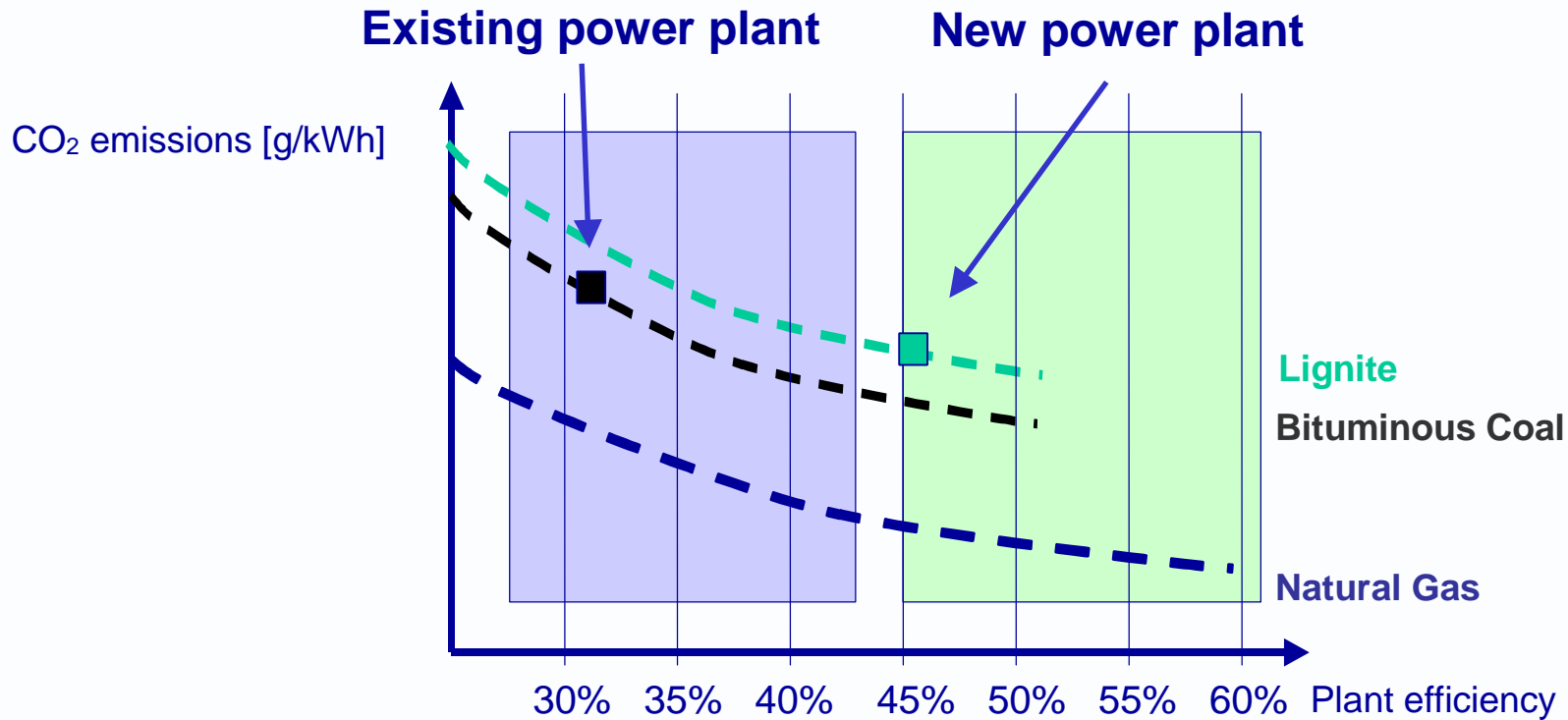


	Limiting pollutants production	Removing pollutants post-combustion
Installed base	<ul style="list-style-type: none"><li>● Retrofit to improve thermal / environmental efficiency</li></ul>	<ul style="list-style-type: none"><li>● Emissions control Back-end equipment</li><li>● Long-term: Oxy firing and CO2 capture retrofits</li></ul>
New power plants	<ul style="list-style-type: none"><li>● Fuel / technology mix</li><li>● Long term: USC</li></ul>	<ul style="list-style-type: none"><li>● Emissions control equipment</li><li>● Long-term: integrated CO2 capture systems</li></ul>

**Clean Combustion solutions: limiting emissions while maintaining power plant economics**

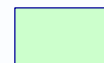


# From service to retrofit and new plants...



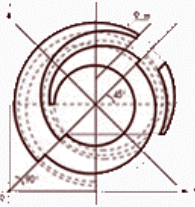
## Service and Retrofit

- Consultancy/Assessment
- Fuel switch
- CO2 Cut (retrofit, rehabilitation)



## New Equipment

- Move to high efficient new plants
- Fuel switch
- Carbon capture and storage



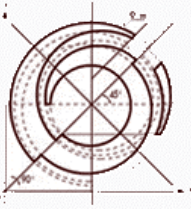
# CO<sub>2</sub> reduction potentials for typical plant components / systems



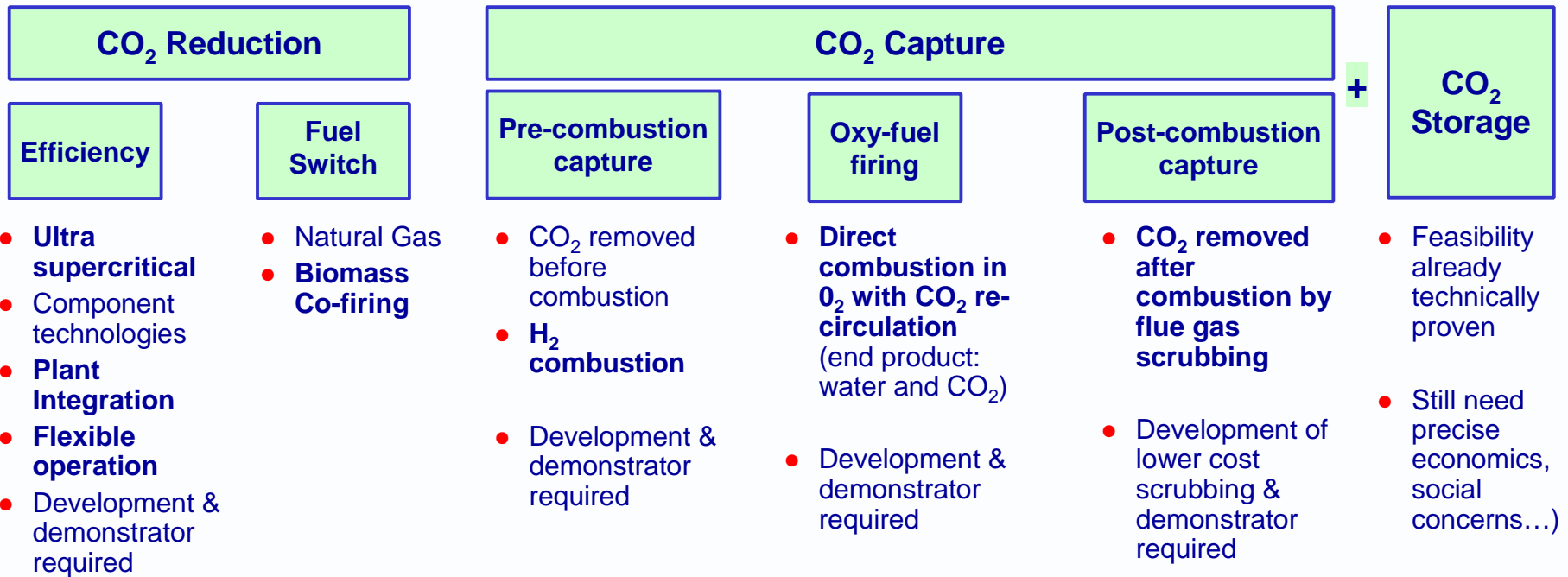
**Basis: Plant Size 200MW, Plant Efficiency=40%, OH=5000h**

Component / System	Variation of Parameter	CO2 reduction in t CO2/a
<b>Boiler</b>		
Efficiency air preheater	1,0%	-14400
Exhaust gas temperature (28 MJ/kg)	10 °C	-46800
Unburned carbon	1,0%	-108000
Sootblowing	1 kg/s	-68400
<b>Turbine</b>		
HP turbine efficiency	1,0%	-64800
LP turbine efficiency	1,0%	-46800
<b>Water Steam Cycle</b>		
Live steam temperature (subcritical unit)	+10 °C	-28800
Live steam temperature (supercritical unit)	+10 °C	-39600
Hot reheat steam	+10 °C	-25200
<b>Total Plant</b>		
Auxiliary load	-1,0%	-108000

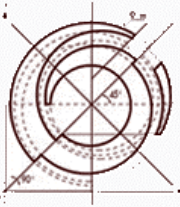
**A total plant approach is required**



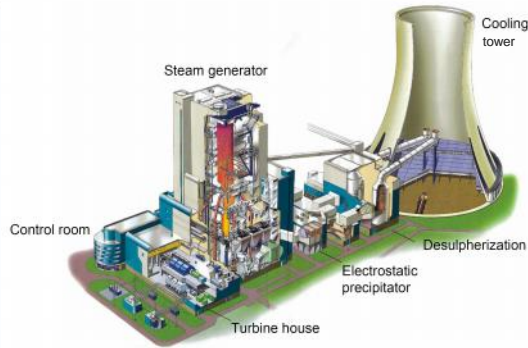
# Our R&D approach to CO<sub>2</sub>



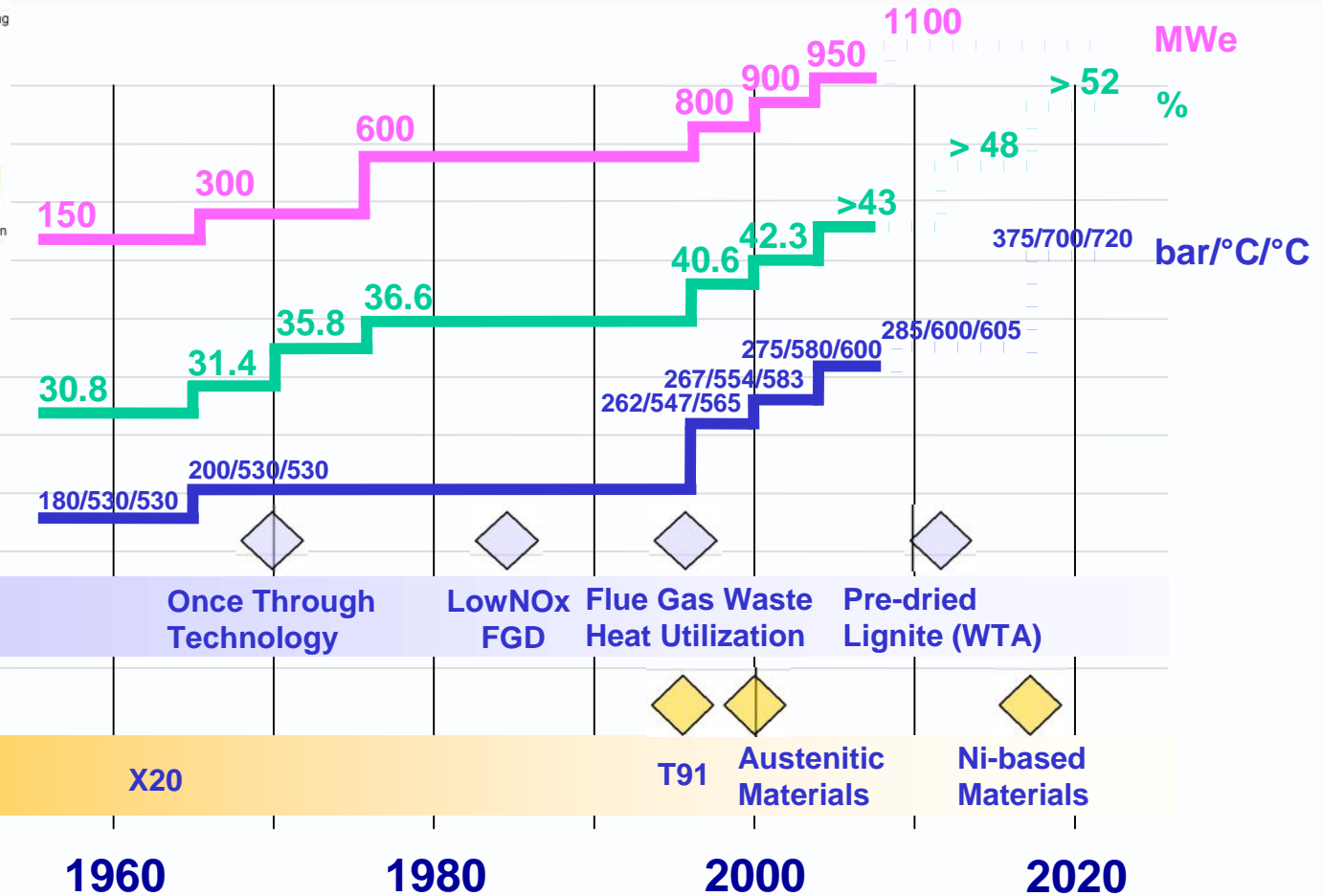
Technologies evaluated



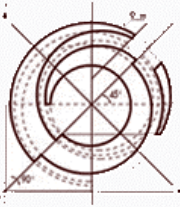
# Lignite Fired Steam Generator Roadmap



- Power Output (gross)
- Efficiency (net)
- Steam Parameter



**ALSTOM's lignite product technology targets higher efficiency by pre-drying and steam cycle improvements**

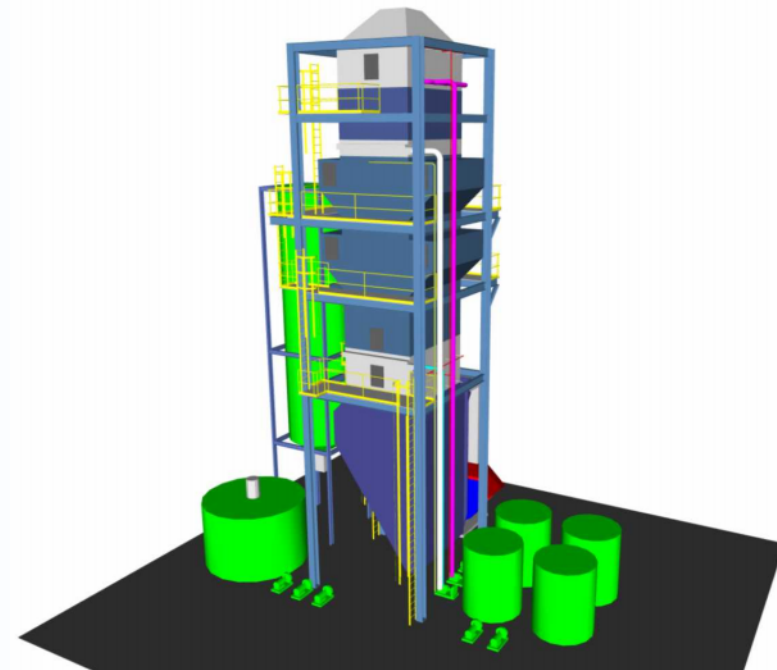


# Integrated Multi Pollution Control

**ALSTOM**

- **Several stage APC system**
  - Individual stages are commercially proven
- **Uses limestone and other, readily available reagents**
  - Limestone
  - Peroxide in solution
- **Produces reusable byproduct(s) (gypsum)**
- **Better cost/performance ratio:**
  - Lower permitting costs
  - Lower material costs
  - Lower erection costs
  - Lower operating costs
  - Lower maintenance costs
  - Additional SO<sub>2</sub> credits generated (economic value)
- **Removes:**
  - > 99.5% of SO<sub>2</sub>
  - > 90% of Hg
  - Improved PM<sub>10</sub>/PM<sub>2.5</sub> removal
  - Potential for NOx Removal (TBD)

**Controls SO<sub>x</sub>, PM<sub>10</sub>/PM<sub>2.5</sub> & Mercury**

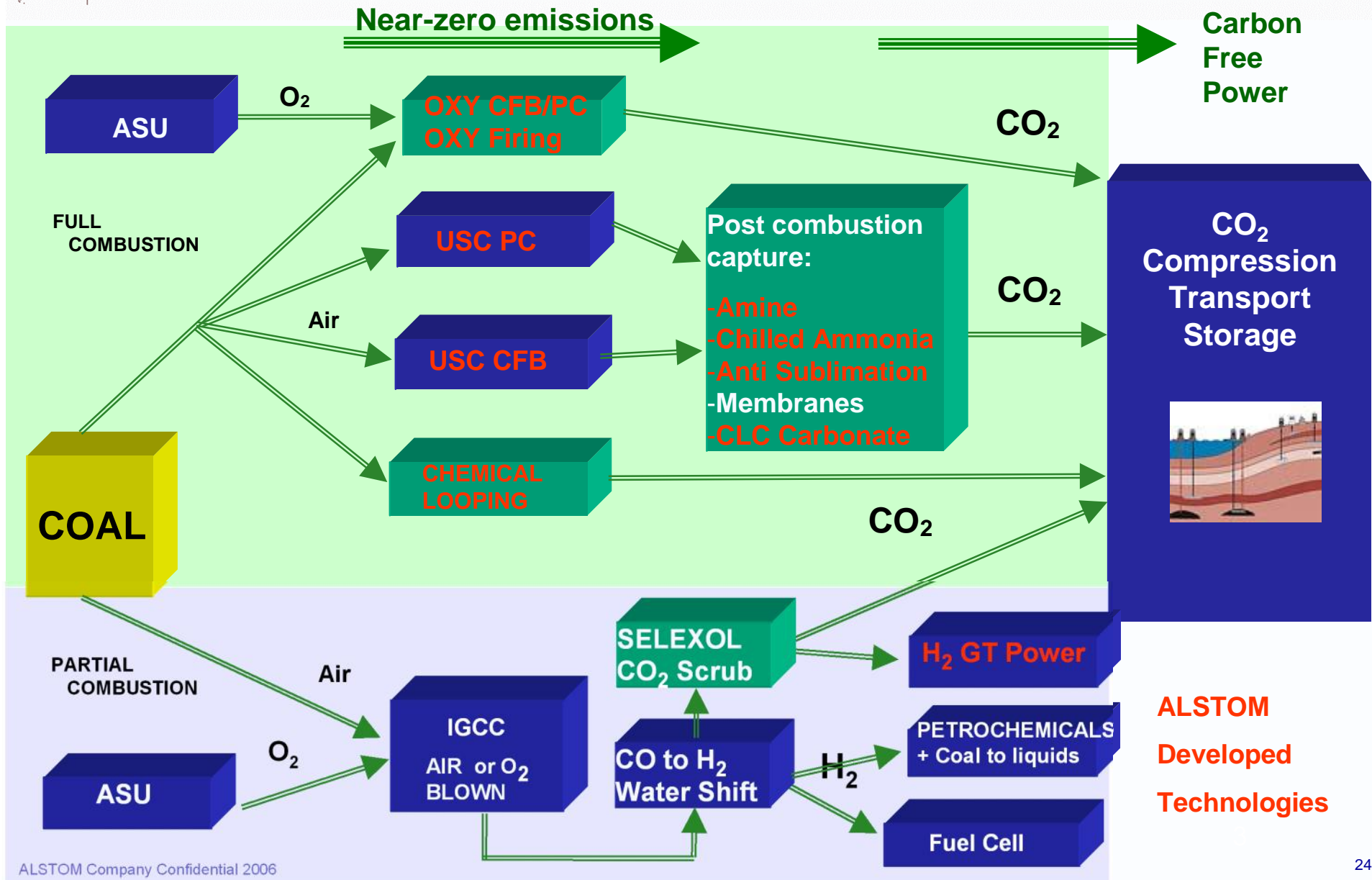


**System will control outlet emissions to 'near zero' levels**



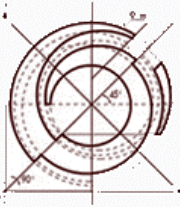
# A vision for Clean Coal Power portfolio of technologies

# ALSTOM



ALSTOM Company Confidential 2006

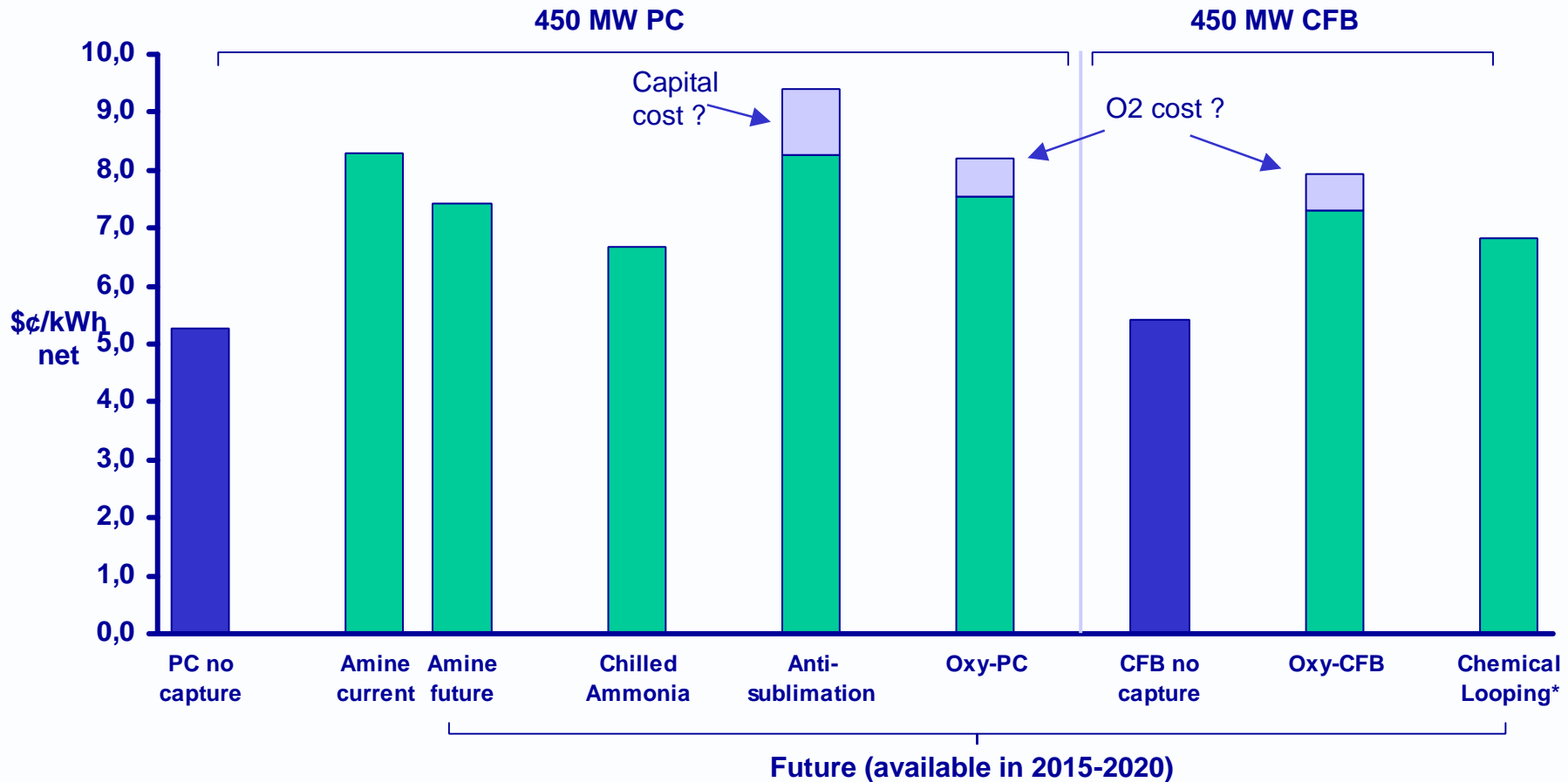
24



# Cost of electricity Comparative assessment

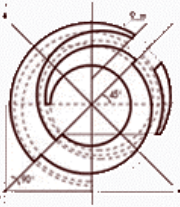


**For all technologies based on 450MW PC and CFB plants**



Avoidance cost (\$/ tonne)	Amine current	Amine future	Chilled Ammonia	Anti-sublimation	Oxy-PC	Oxy-CFB	Chemical Looping*
	47	33	21	45-64	35-46	29-39	20

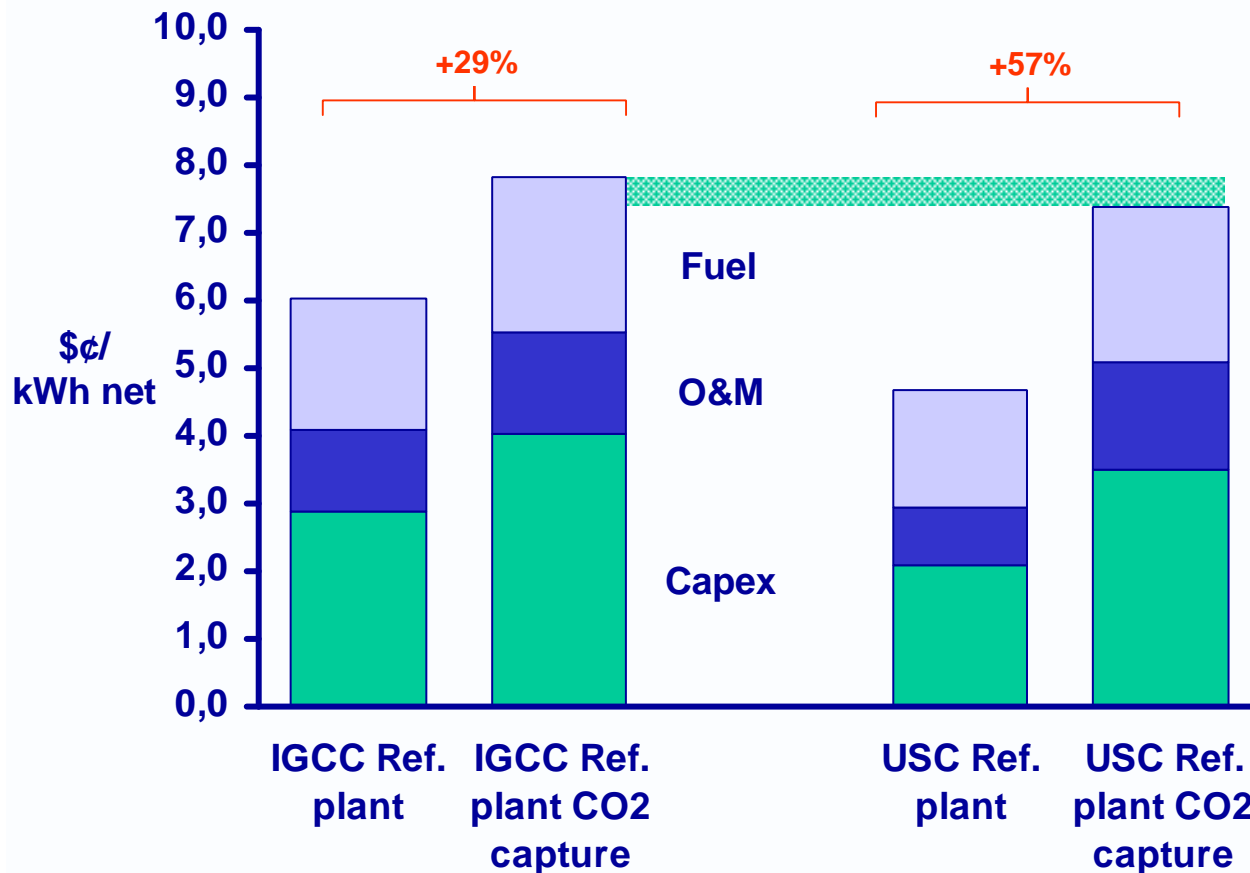
**In the size range of CFB boilers, oxy-CFB is slightly more competitive than oxy-PC and very comparable to amine; ammonia and chemical looping seem to have an edge**



# Cost of electricity Comparative assessment

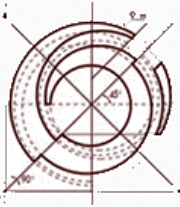


## 2005 IGCC Reference plant vs. USC (with CO2 capture)



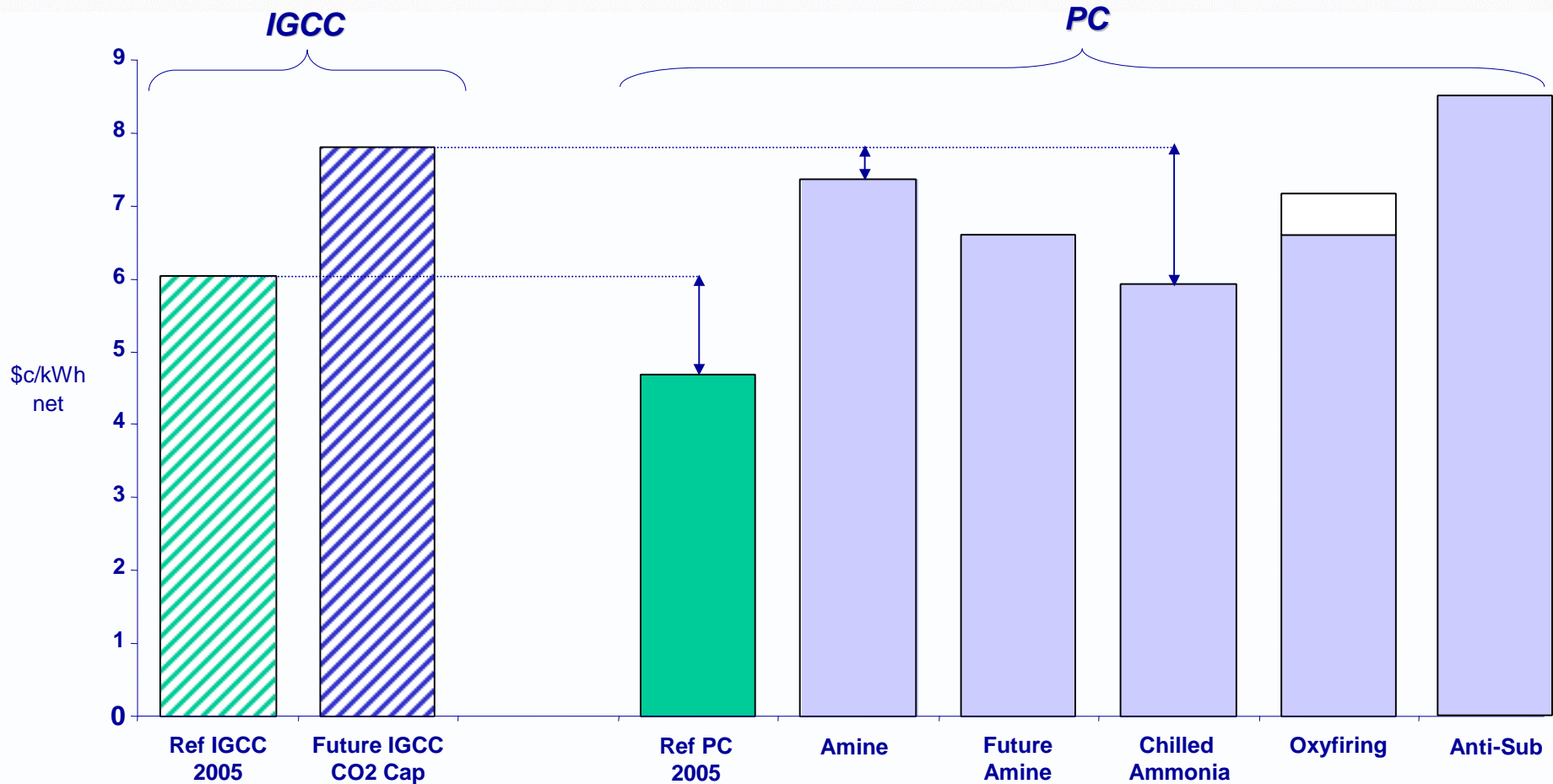
- 2005 IGCC scenario with CO2 capture is theoretical, as F-class GT capable to burn H2 is not yet available
- USC Reference plant with CO2 capture key assumptions:
  - Amine-based capture
  - Availability: 86%
  - Efficiency: 44.3%

- CoE of IGCC vs. USC
  - Without capture: +29%
  - With capture: +6%

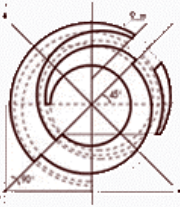


# Cost of Electricity 800MW Coal Plant

ALSTOM



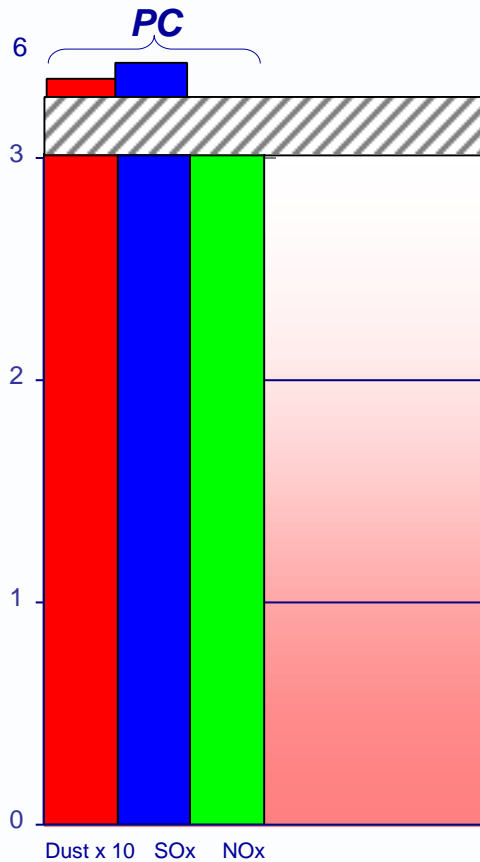
- High efficiency Pulverised Coal offers lowest cost of power now
- Three best options for CO2 capture from coal: Advanced post combustion capture and Oxy-firing



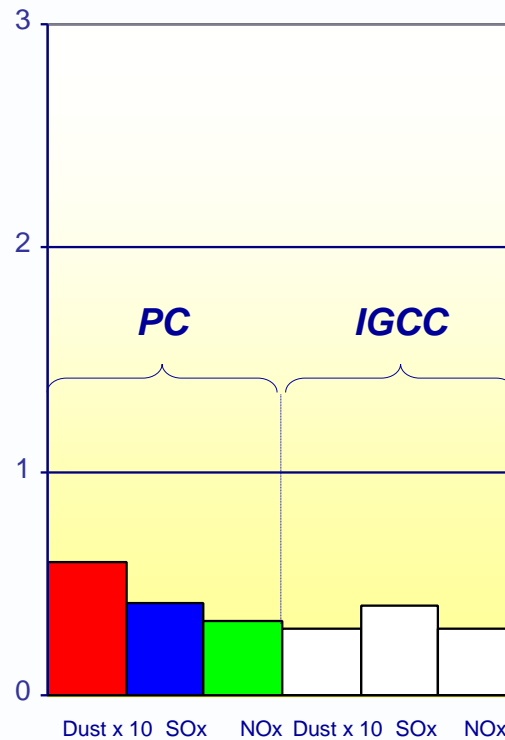
# Emissions Comparison

**ALSTOM**

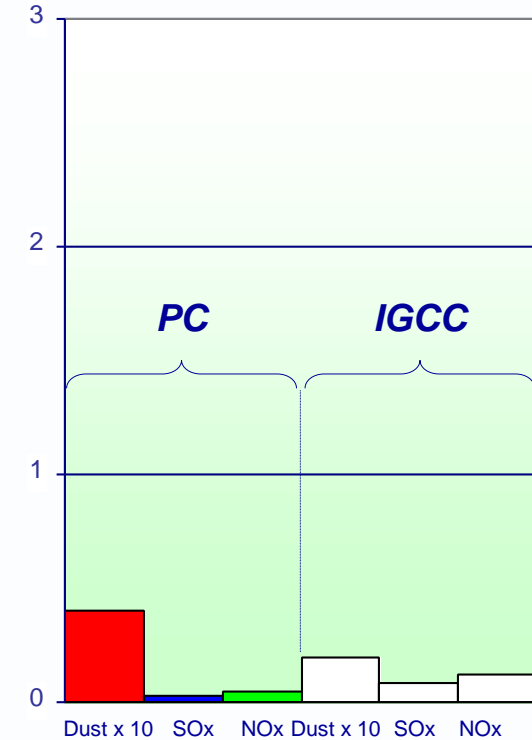
**1980s**



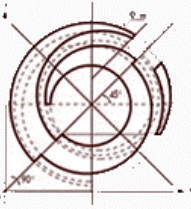
**Today**



**Future**



- Coal has been considered a dirty fuel. Technology now allows it to become clean
- High efficiency modern “conventional” coal plants are as clean as IGCC



# Comparative assessment



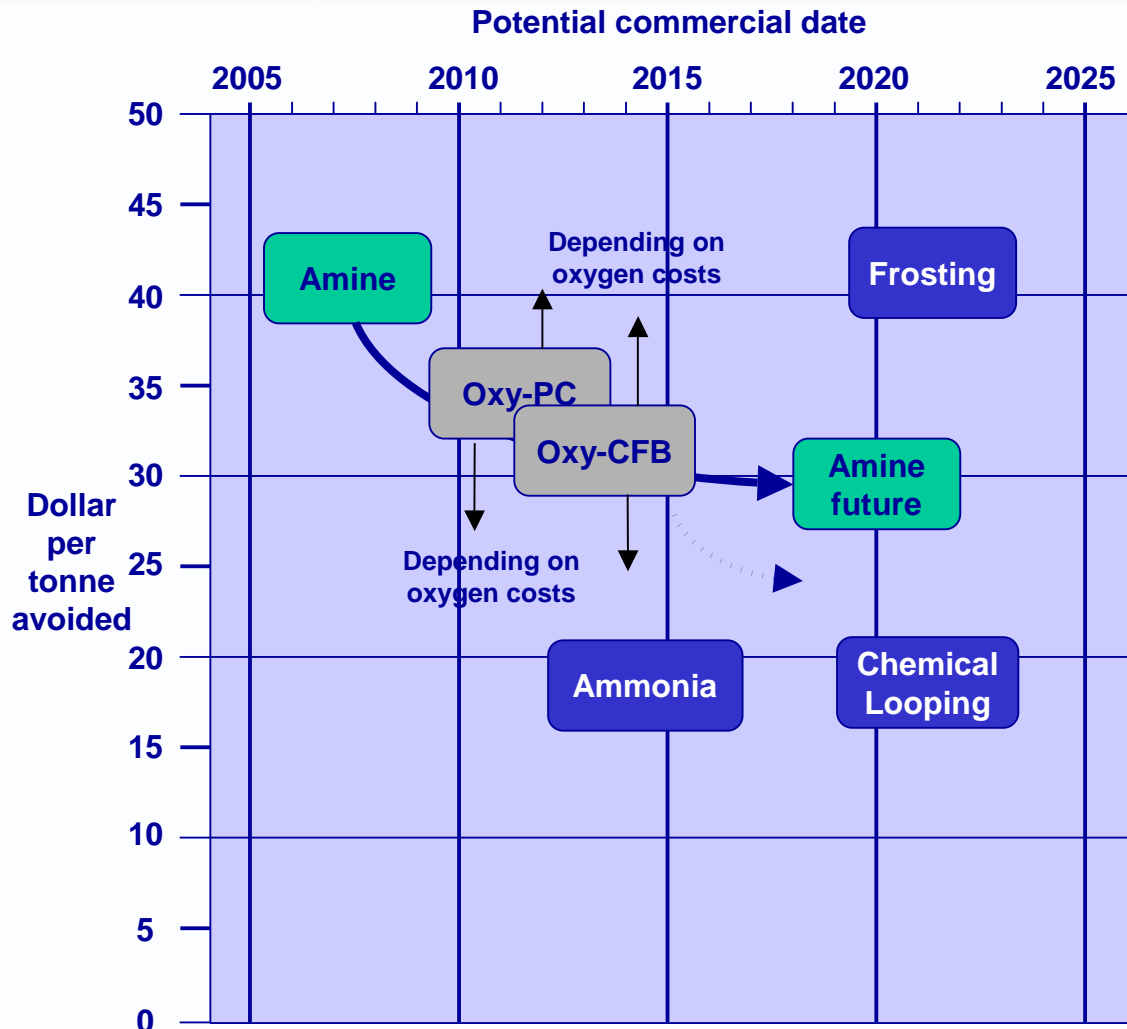
	Space for 800MW PC plant (500 x 500m)	Estimated retrofit investment	Estimated plant shutdown time	Distortion of main plant steam cycle	Impact on main plant output
Amine	210 x 210 m	Around \$235m*	12 weeks	Steam extraction between IP and LP sections	25% decrease in net output
Ammonia	Size of an FGD (estimated at 60 x 60 m)	Around \$190m*	A few weeks (most likely comparable to amine)	Steam extraction between IP and LP sections	10% decrease in net output
Anti-sublimation	Around 120 x 80m Potential to reach 80 x 80 or 50 x 50m	Between \$435m and \$480m	2 weeks	No impact	12-25% decrease in net output

Note : \*Based on greenfield costs of capture system with a 20% retrofit premium for steam extraction / integration

**Post-combustion systems can be considered as retrofitable, causing only a few weeks of plant shutdown; space and decreased plant output are the main obstacles**



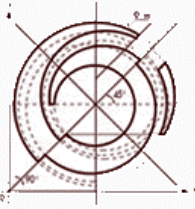
# Comparative assessment



- Oxy-PC and Oxy-CFB are clearly competitive with amine, their cost depend highly on oxygen supply
- Chemical Looping could be a long term high potential option for green field plants
- Overall a single winning technology doesn't seem likely in the medium term



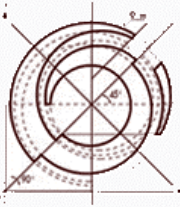
**When comparing all CO2 capture technologies we see a long term edge for ammonia and CLC**



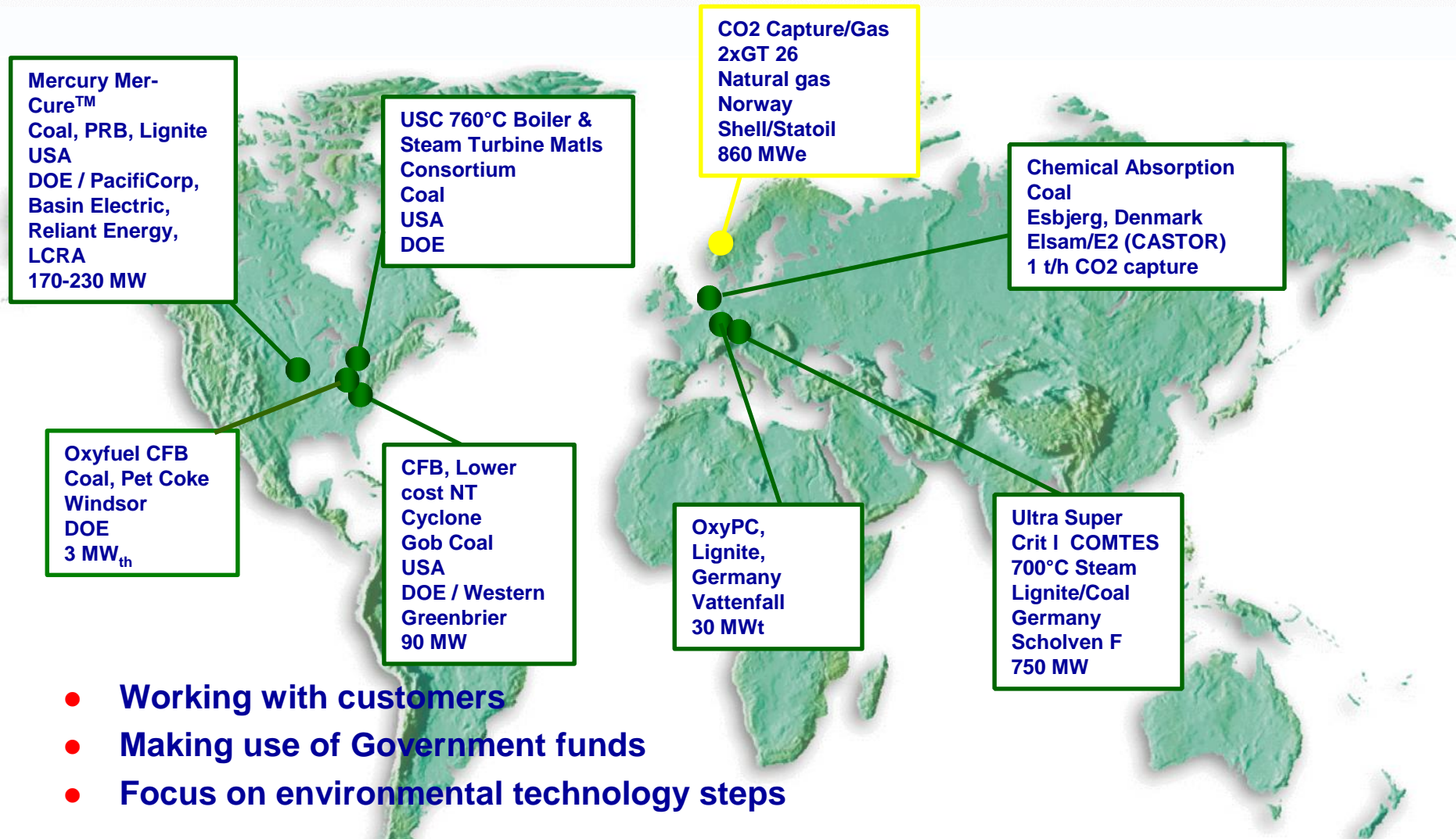
# Status of R&D on capture technologies

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- Amine: participation in the CASTOR program, first 1000 hrs run test results being analysed, program for new solvents testing has started.
- Turbine exhaust gas recycle: proof of concept gate review completed, seeking partners for pilot testing.
- Chilled Ammonia: licence purchased from conceptor, pilot testing initiated, promising results.
- Frosting: Long pilot run test completed, results are being evaluated, economics do not look favorable.
- Oxyfiring: selected by Vattenfall for Oxy-PC 30 MWt demo plant to start in 2008, 3 MWt Oxy-CFB pilot evaluation completed in Windsor potentials partnerships for Oxy-CFB demo are actively considered
- Chemical Looping Combustion: lab scale experiments on-going with university of Chalmers and in our labs of Windsor
- H2 combustion: on-going development of our AEV burners for our GT13E2 turbine



# Plant demonstration partnerships: 8 examples



- Working with customers
- Making use of Government funds
- Focus on environmental technology steps

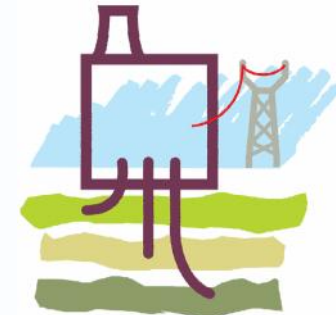
**We have currently 25 demonstration partnerships with our customers**



## Priorities summary

**ALSTOM**

- Ultra super critical steam plant based on hard coal and lignite
- Multi pollution control for very low emissions of conventional pollutants
- Post-combustion CO<sub>2</sub> removal from both coal and gas plant
- Oxy-fuel combustion of solid fuel
- Fuel flexibility and H<sub>2</sub> for gas turbine
- Retrofit and new equipment solutions
- Continued research and development



**The Clean Combustion Specialist**

The ALSTOM logo is centered on a white semi-circular background. The letters 'ALST' and 'M' are in a dark blue, bold, sans-serif font. The letter 'O' is replaced by a red circular graphic consisting of three concentric, slightly offset rings, creating a sense of motion or a stylized 'O'.

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