October, 2006

Clean Coal Combustion Competitive Solutions for Near Zero Emissions

Sean Black
Environmental Control Systems

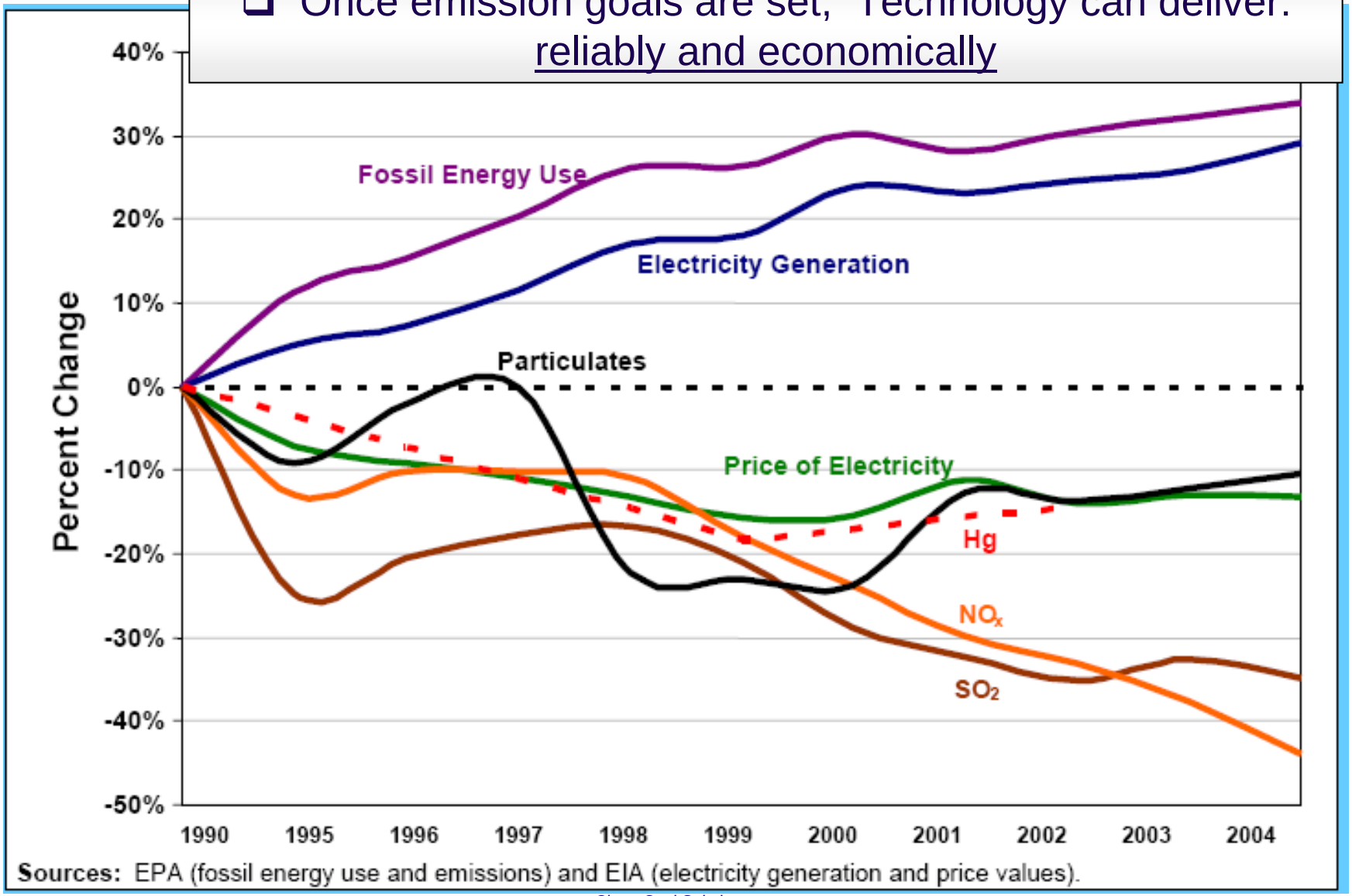
Bringing you a World of Experience in Clean Air Solutions

ALSTOM

Coal Based Power Options
Emissions

ALSTOM

- Once emission goals are set, Technology can deliver: reliably and economically



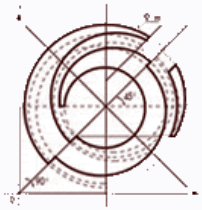
Sources: EPA (fossil energy use and emissions) and EIA (electricity generation and price values).

Advanced CFB/FDA Technology

- Successful integration of ALSTOM CFB and back-end APC technologies
- Emissions (Permit Levels):
  - SO2: 0.2 lb/MMBTU
    - > 98% removal
  - NOx: 0.10 lb/MMBTU
  - PM/PM10 : 0.015 lb/MMBTU
- Excellent fuel flexibility
- Uses low cost limestone
- Combusts wide range of fuels
  - Up to 4.5% S and 20% ash

EKPC E.A. Gilbert Station Unit 3


ALSTOM



FLOWPAC
Karlshamm Performance Levels

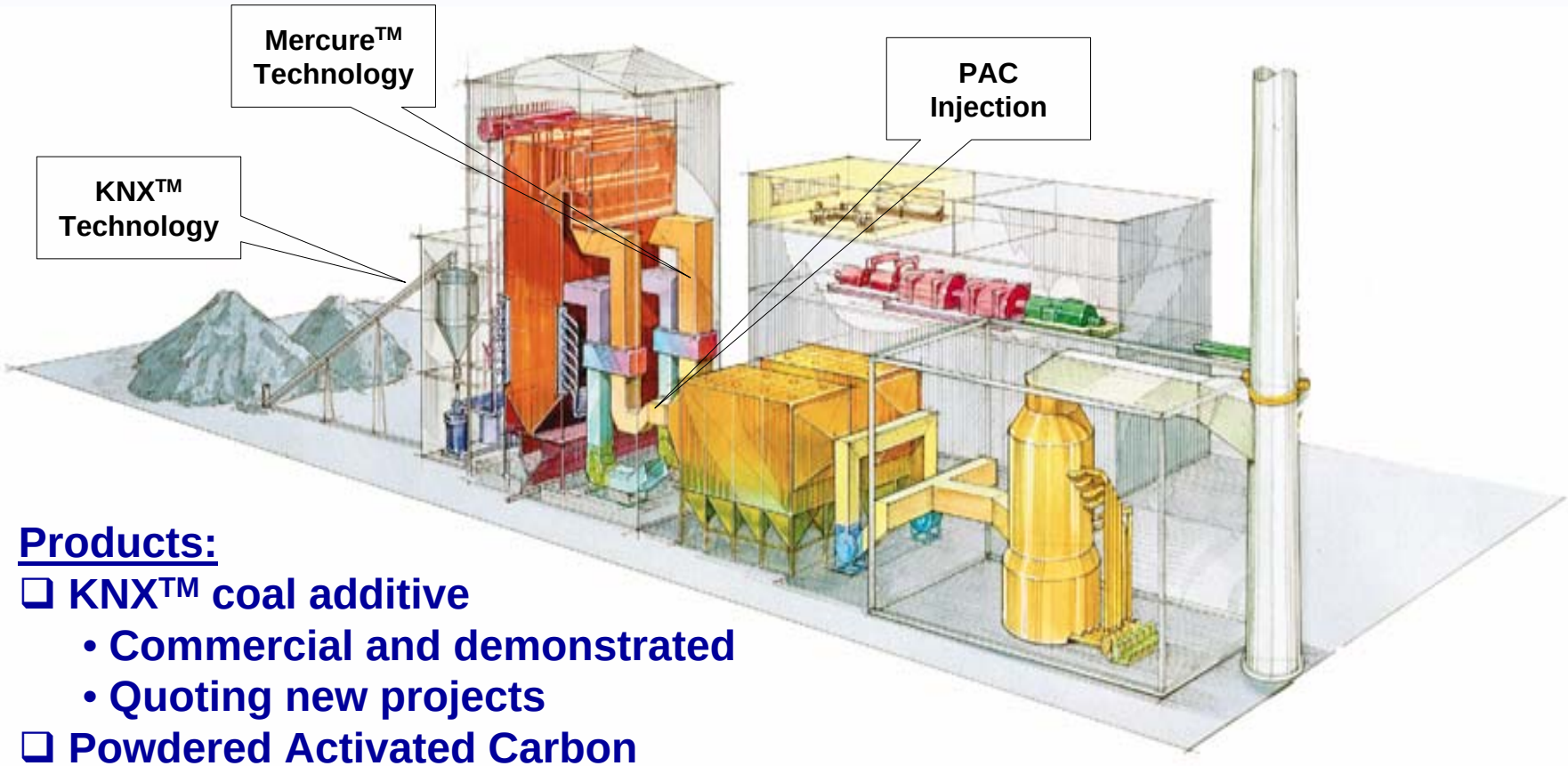
ALSTOM

Sulfur Content in the Fuel: 2.5%

Inlet Gas Conditions (at ESP outlet)	**English**	**Metric**
Flue Gas Flow	**~ 870,000 acfm**	**1,080,000 Nm^3/hr**
Flue Gas Temp	**270°F**	**130°C**
Particulate Matter (PM)	**0.025 lb/MMBTU**	**30 mg/Nm^3**
Outlet Gas Conditions (at stack)		
SO_2 (>99% w/ no additives)	**< 19 ppmv**	**< 55 mg/Nm^3**
SO_3 (~70% removal)	**< 1 ppmv**	**< 2 mg/Nm^3**
PM (>60% removal -oil soot)	**< 0.01 lb/MMBTU**	**< 2 mg/Nm^3**

> 1,800 MW in Operation/Development

When Additional Control is Needed
Mercury Capture Technologies



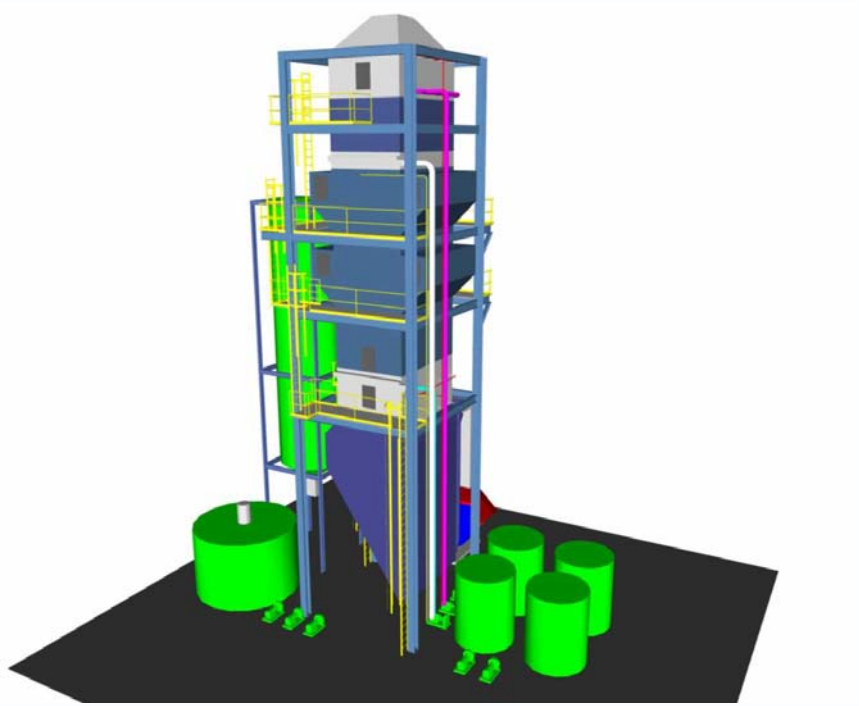
Products:

- ❑ **KNX™ coal additive**
  - **Commercial and demonstrated**
  - **Quoting new projects**
- ❑ **Powdered Activated Carbon**
  - **Used with existing/new ESP or FF**
- ❑ **Mercure™ Halogenated PAC**

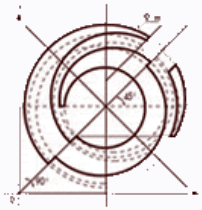
ALSTOM (Multi-pollutant) APC System

- Integrated APC system based around commercially proven and reliable technologies
- Uses readily available reagents
- Produces reusable byproduct(s)
  - No impact on fly ash
- Superior cost/performance ratio:
  - Compact design reduces capital costs
  - Less moving parts reduces maintenance costs
  - Superior environmental performance
- Targeted emissions levels:
  - SO2: 0.02 lb/MMBTU (> 99.5%)
  - Hg: 1.0 lb/TBTU (> 90%)
  - PM: 0.01 lb/MMBTU (99.99%)
  - NOx: 0.05 lb/MMBTU w/SCR

Controls SO_x, $PM_{10}/PM_{2.5}$ Mercury & NOx



Control outlet emissions to 'near zero' levels

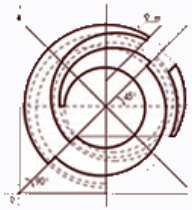


Ultra Clean Coal Combustion Emissions Control Capability

ALSTOM

- Today's state-of-the-art
  - NOx >95% reduction with optimized firing systems and SCR
  - SO2 >99% capture with WFGD
  - Particulates 99.99% capture
  - Hg 80- 95% capture (coal dependent)
- Next steps
  - Continued improvements
  - Integrated Multi-pollutant systems to reduce costs
  - High Hg capture on all coals (without reliance on ACI)
  - Introduction of CO2 capture

Emissions Reductions Continue



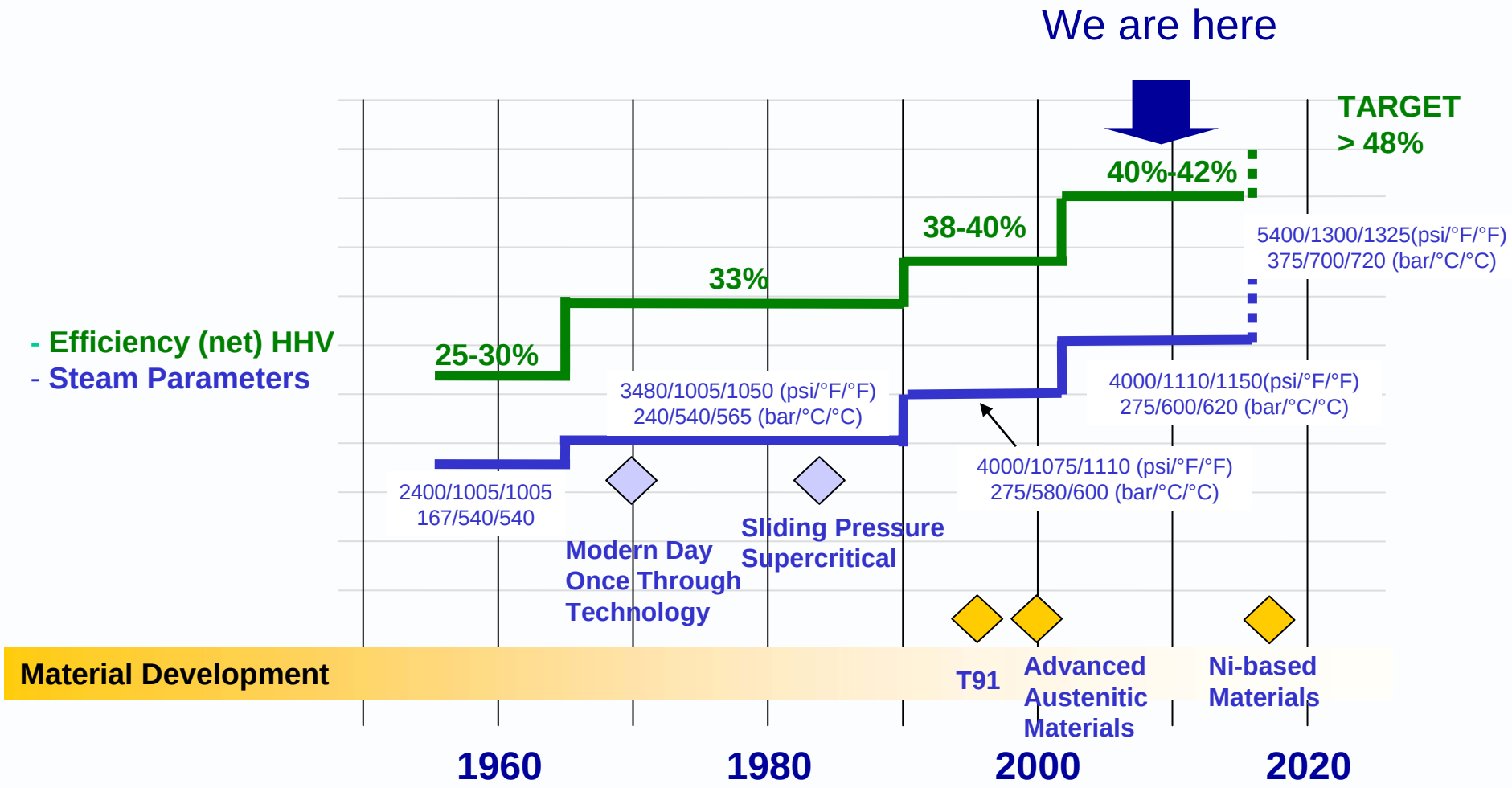
Paths to Carbon Free Power

ALSTOM

- Efficiency – Achieve >48% HHV
  - Ultrasupercritical PC
  - Emphasis on advanced materials
- Co-firing of biomass
  - Partial replacement of fossil fuels in PC/CFB – proportional reduction in CO2
- Post Carbon Capture – Achieve >90% CO2 capture
  - Multiple options under development to achieve competitive COE for Clean Coal Combustion and IGCC with CO2 capture
- New Combustion Cycles

Maximize carbon reduction by efficiency – then capture for sequestration

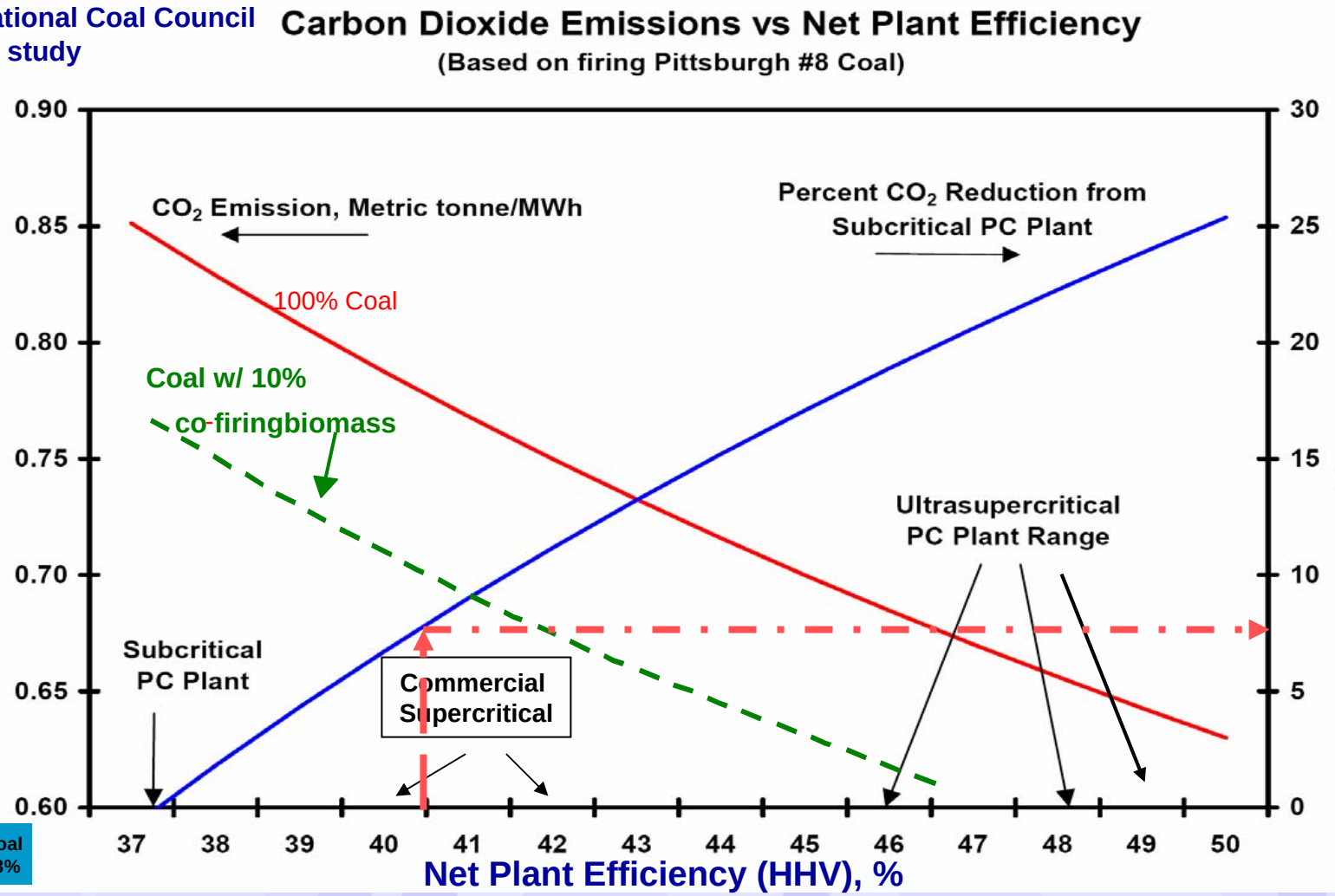
Progression of Plant Efficiency via Advanced Steam Conditions and Plant Designs



Continuing Advancements = lower fuels costs and emissions

Efficiency – Reduce Carbon In Critical to emissions strategy

Source: National Coal Council
From EPRI study



Existing US coal fleet @ avg 33%

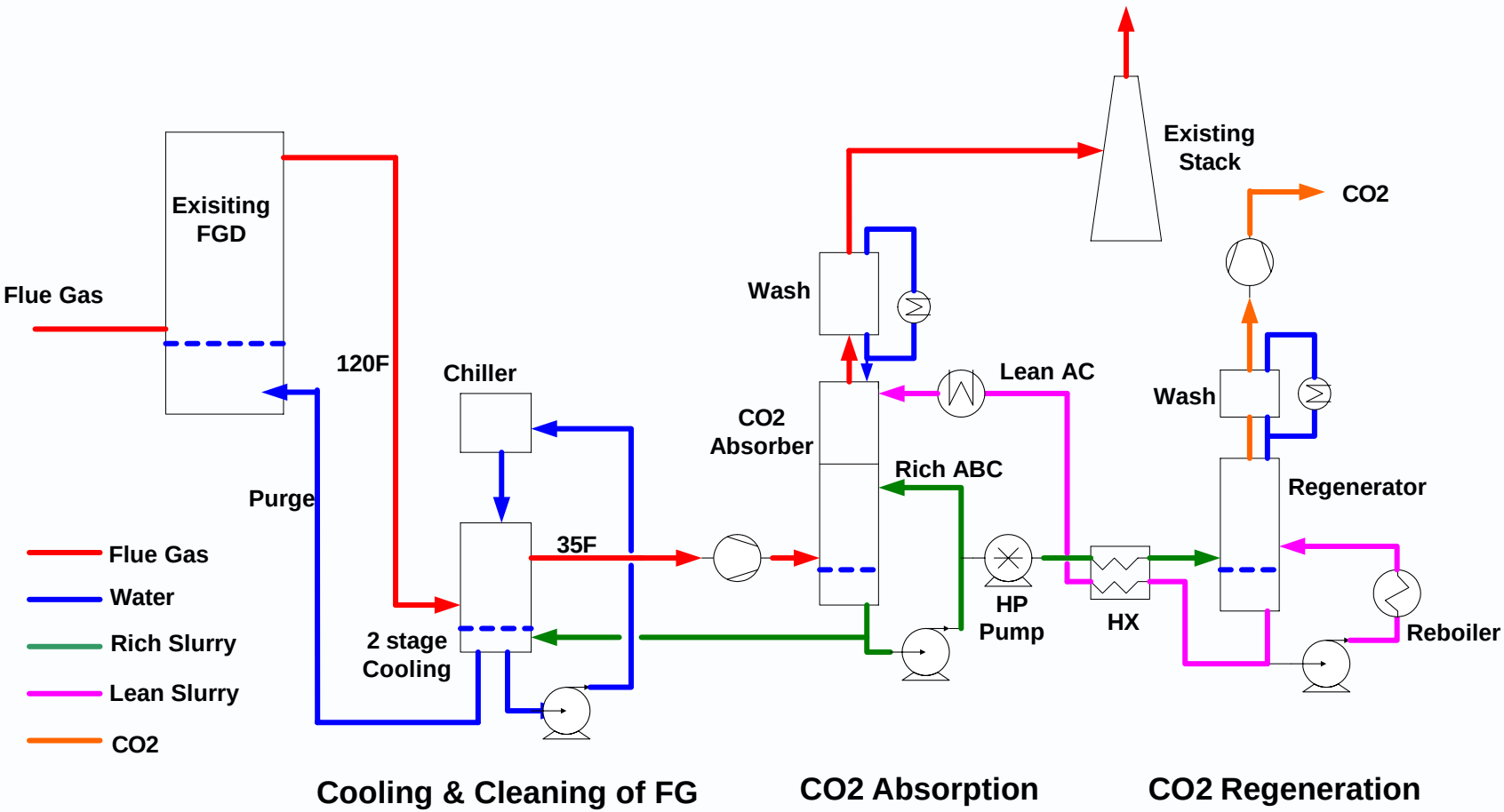
Steam cycle increase from Subcritical to USC yields up to 25% emissions reduction in lbs/Mwhr

Low Carbon Combustion
Alternate Paths to CO2 Capture

Technology	Status
CO_2 Scrubbing options – ammonia based	Demonstration in 2006. Advantage of lower costs than Amines. Applicable for retrofit & new applications
Advanced Amine Scrubbing	Further Improvements in Solvents, Thermal Integration, and Application of Membranes Technologies Focused on Reducing Cost and Power Usage – Multiple suppliers driving innovations
CO_2 Frosting	Uses Refrigeration Principle to Capture CO_2 from Flue Gas. Process Being Developed by Ecole de Mines de Paris, France, with ALSTOM Support
CO_2 Wheel	Use Regenerative Air-Heater-Like Device with Solid Absorbent Material to Capture ~ 60% CO_2 from Flue Gas. Being Developed by Toshiba, with Support from ALSTOM
CO_2 Adsorption with Solids	Being Developed by the University of Oslo & SINTEF Materials & Chemistry (Oslo, Norway), in Cooperation with ALSTOM

NH3-CO2-H2O Process

Schematic of Ammonia-based CO2 Capture System



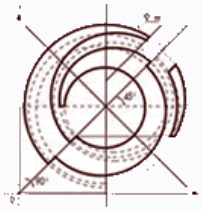
Basic Comparison with MEA

	Supercritical PC Without CO_2 Removal	SCPC With MEA CO_2 Removal Parsons Study	SCPC With NH_3 CO_2 Removal Current Study
Coal Feed rate, lb/hr	333,542	333,542	333,542
Coal heating value, Btu/lb (HHV)	11,666	11,666	11,666
Boiler heat input, MMBtu	3,891	3,891	3,891
LP Steam extraction, lb/hr for reboiler	0	1,215,641	179,500
Steam Turbine Power, kWe	498,319	408,089	484,995
Generator loss, kWe	(7,211)	(5,835)	(7,018)
Gross plant, kWe	491,108	402,254	471,301
Plant Auxiliary Load (IDF, FGD, BFW pumps, Water pumps, Cooling Towers, CO2 unit, Chillers, CO2 compressor, BOP), kWe	(29,050)	(72,730)	(53,950)
Net Power Output	462,058	329,524	421,717
Net efficiency, % HHV	40.5	28.9	37.0
Avoided Cost, $/ton CO2	Base	51.1	19.7

We Energies Pleasant Prairie
Host Site Location for 5MW Pilot

we energies

EPRI ELECTRIC POWER RESEARCH INSTITUTE



Carbon Free Power
Advanced Combustion

ALSTOM

- Advanced Combustion
  - Oxygen Firing – Direct concentration of CO2 to >90% for reduced capture costs
  - Chemical Looping –Leapfrog technology with potential to achieve significantly lower costs than PC/CFB/IGCC

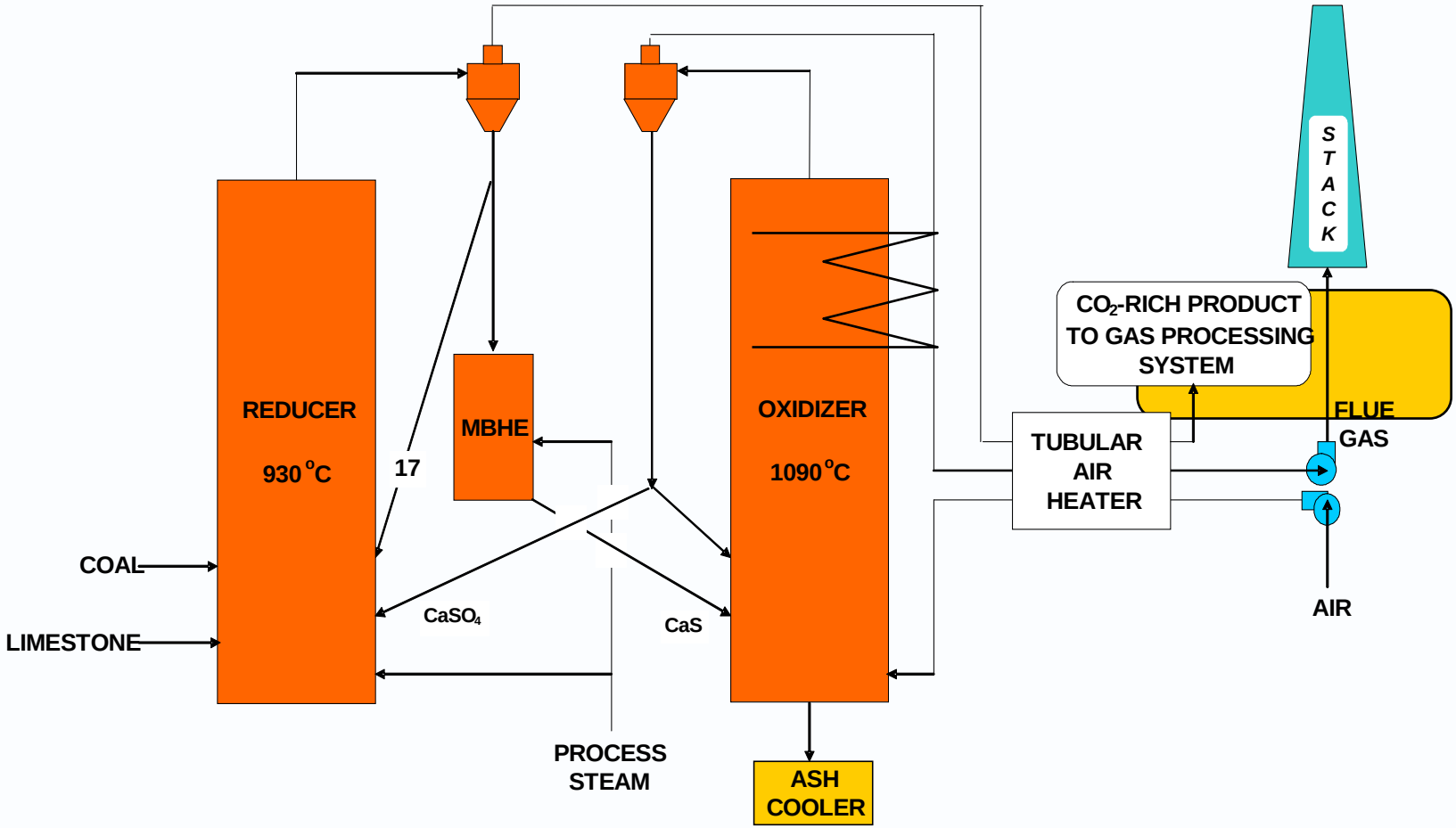
30 MWth Oxy-fired PC Pilot Plant – Vattenfall

Location of pilot plant in the Industrial Park Schwarze Pumpe

Development Steps	Scale-up Factor	Objective	Com	Partners
Laboratory Tests 10 / 55 kWth		Fundamentals of oxyfuel combustion	2004 2005	Universities (Stuttgart, Chalmers, Dresden) Vattenfall, ALSTOM..
Test Plant 500 kWth	1:50	Fundamentals of oxyfuel combustion with flue gas recirculation	2005	CEBra, BTU Cottbus, Vattenfall, ALSTOM
Pilot Plant 30 MWth	1:60	Test of the oxyfuel process chain	2008	Vattenfall..., ALSTOM, others
Demo Plant 600 MWth	1:20	Realisation with CO2 sequestration,	2015	
Commercial Plant approx. 1000 MWel	approx. 4-5		2020	

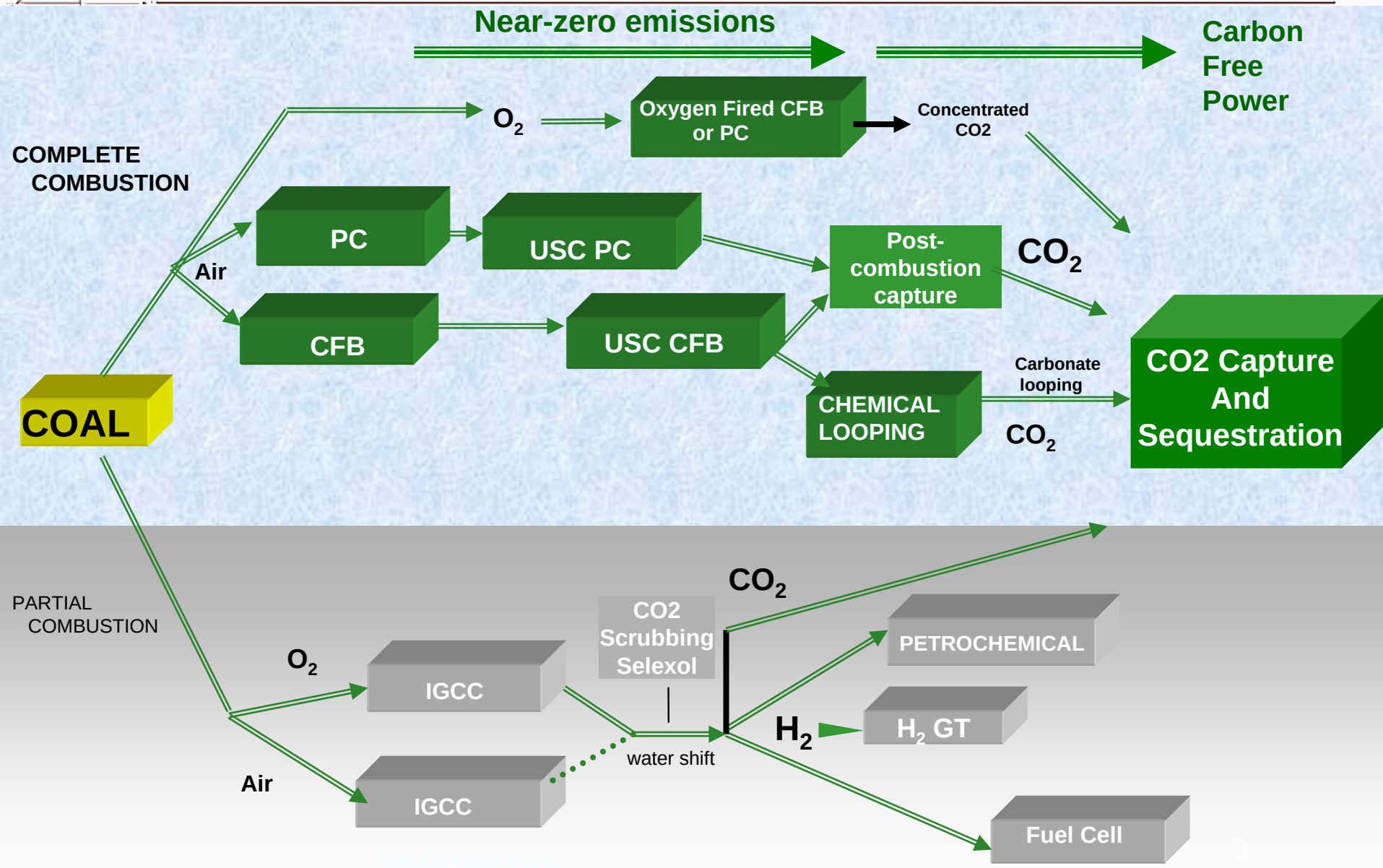
Chemical Looping Combustion

CaS - CaSO4 loop in CFB reactors



Calcium-based CLC process is suited to coal

Our Vision for New Coal Power Portfolio of Clean Technologies



www.alstom.com