The New Clean Coal Technologies

Energy Summit:
"Advancing Domestic Resources in an Era of Carbon Challenges"

December 4, 2007
Stonewall Resort
Roanoke, West Virginia

Joseph P. Strakey

National Energy Technology Laboratory

Office of Fossil Energy

Carbon Capture Technologies
Coal-fired Power Plants

- **Technology options & examples**
  - Pre-combustion (IGCC)
  - Post-combustion (Amine scrubbing, Chilled Ammonia)
  - Oxyfuel combustion
- **Cost/efficiency comparisons (bituminous coal)**
  - New: IGCC, Subcritical PC, Supercritical PC
  - Retrofit
- **FutureGen, R&D Program**
- **Observations / conclusions**

Examples of Pre-Combustion CO_2 Capture Systems

Petcoke Gasification to Produce H_2
Coffeyville, Kansas

Coal Gasification to Produce SNG
Beulah, North Dakota

Source: E.S. Rubin, Carnegie Mellon

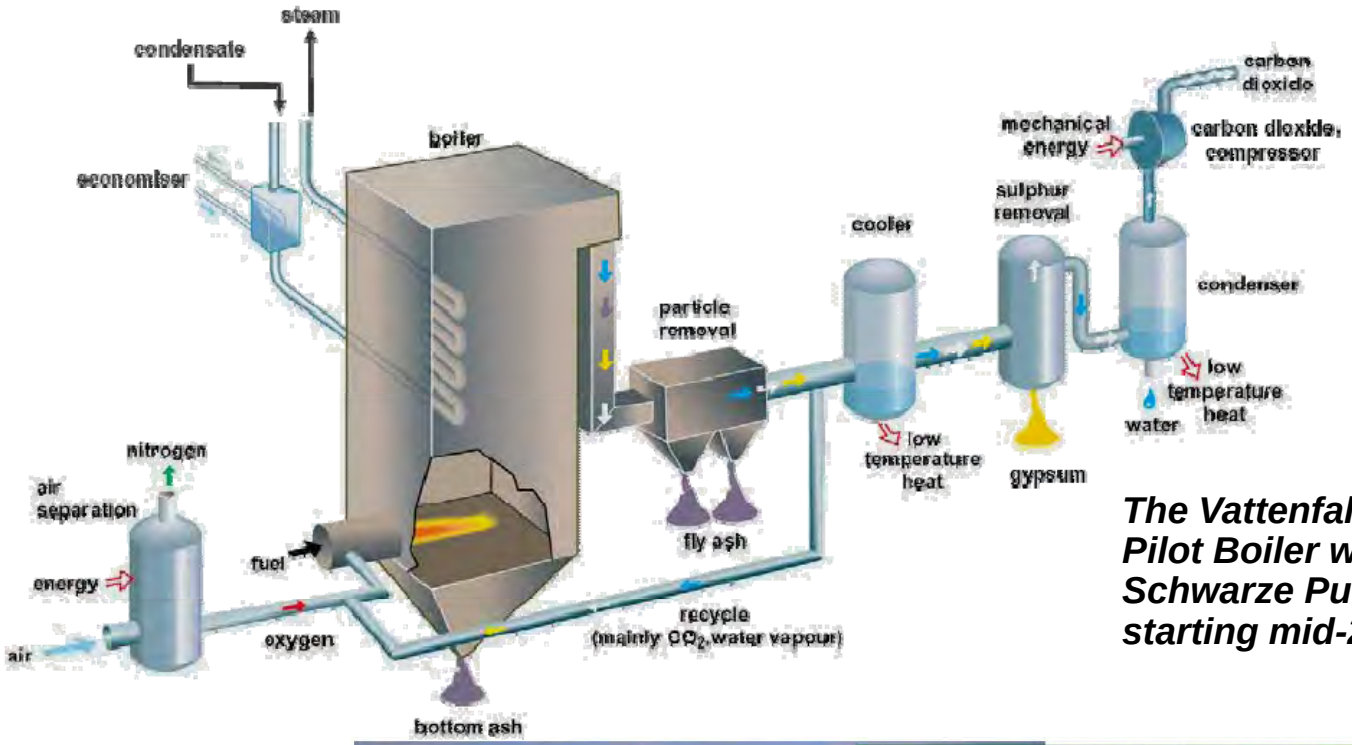
Examples of Post-Combustion CO_2 Capture at Coal-Fired Power Plants

AES Shady Point Power Plant
Captures 2-3% of CO_2 from a 320MWe CFB plant
Panama, Oklahoma

AES Warrior Run Power Plant
Captures 10% of CO2 from a 205 MWe (gross) CFB plant
Cumberland, Maryland

Source: AES and E.S. Rubin, Carnegie Mellon

Example of Oxyfuel Combustion Capture System



The Vattenfall 30 MW_{th} Oxy-Coal Pilot Boiler with CO_2 capture at Schwarze Pumpe (Germany), starting mid-2008

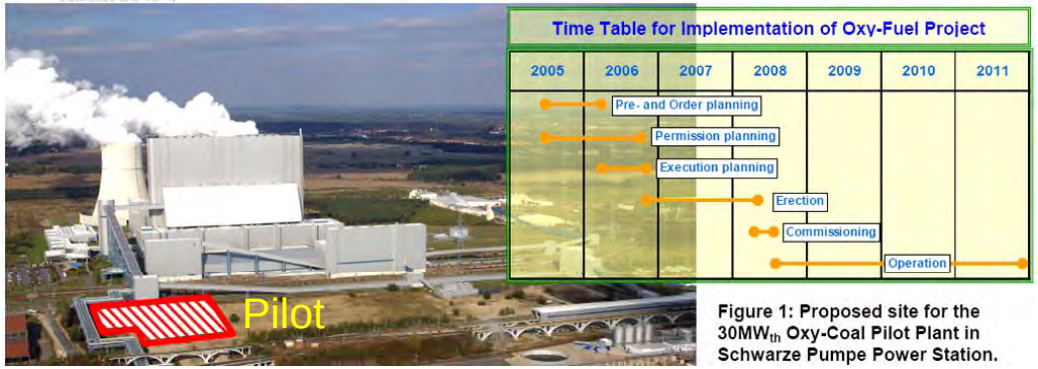
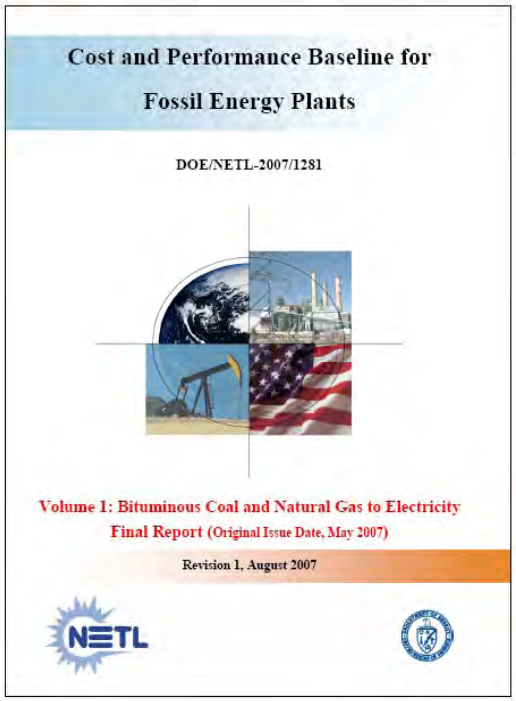
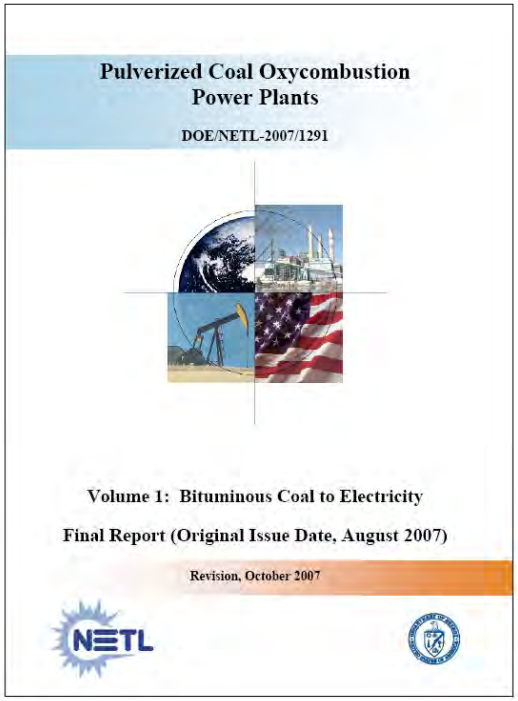
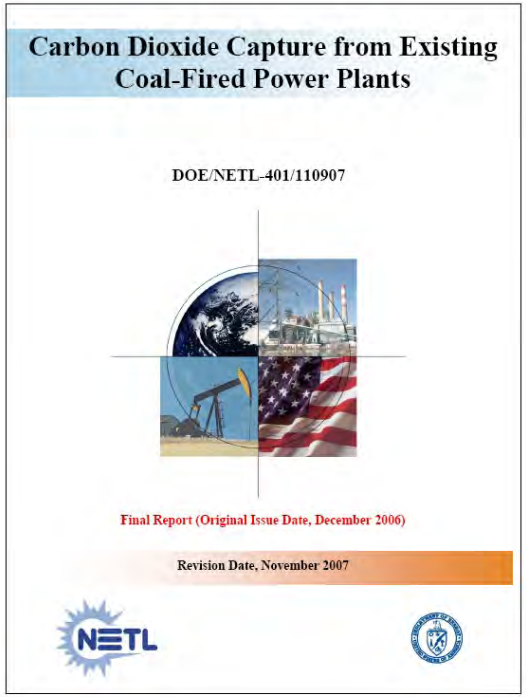


Figure 1: Proposed site for the 30MW_{th} Oxy-Coal Pilot Plant in Schwarze Pumpe Power Station.

Recent NETL Systems Studies

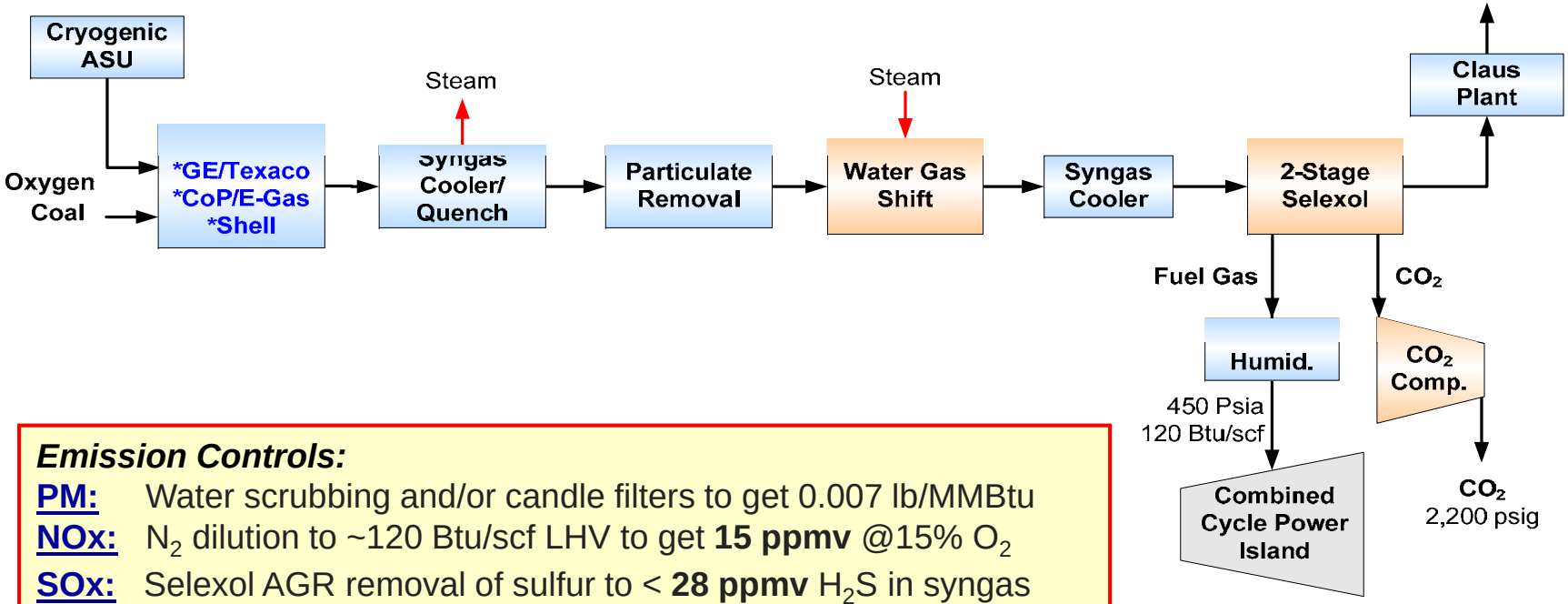






http://www.netl.doe.gov/technologies/carbon_seq/Resources/Analysis/

IGCC Power Plant with CO_2 Capture



Emission Controls:

PM: Water scrubbing and/or candle filters to get 0.007 lb/MMBtu

NOx: N_2 dilution to ~120 Btu/scf LHV to get **15 ppmv** @15% O_2

SOx: Selexol AGR removal of sulfur to < **28 ppmv** H_2S in syngas
Claus plant with tail gas recycle for ~99.8% overall S recovery

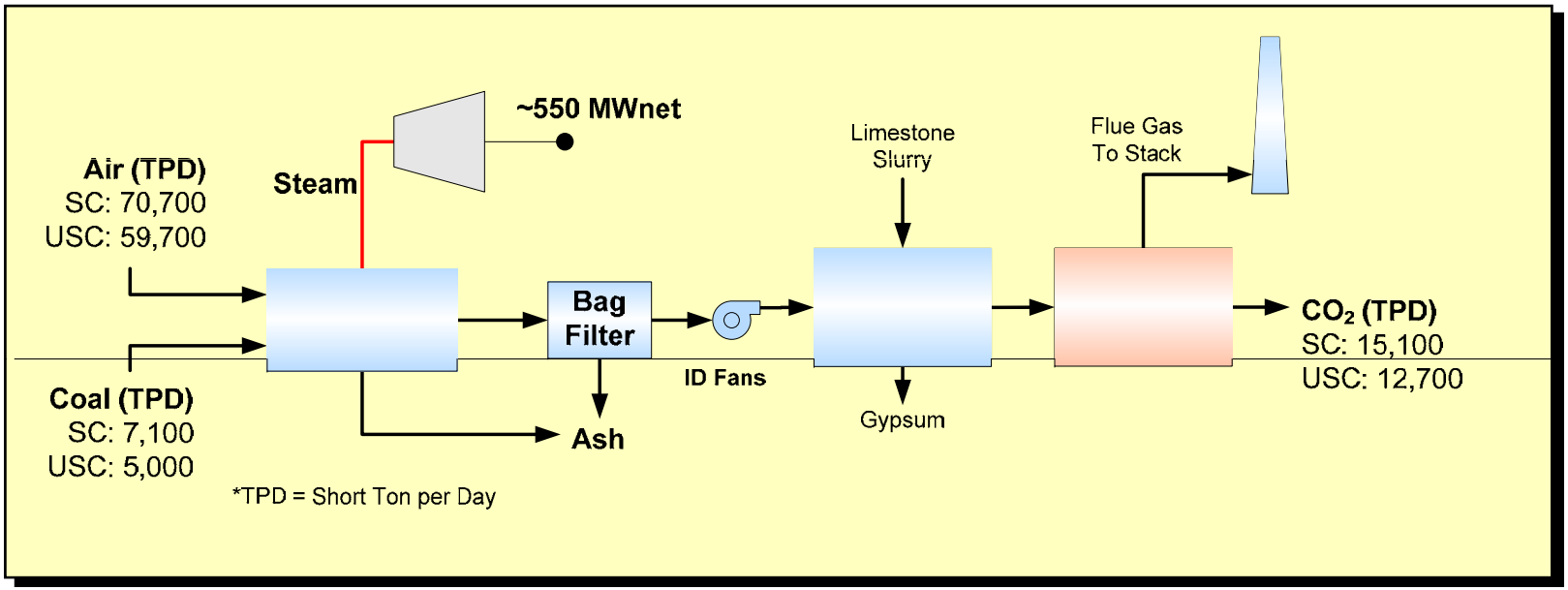
Hg: Activated carbon beds for ~95% removal

Advanced F-Class CC Turbine: 232 MWe

Steam Conditions: 1800 psig/1000°F/1000°F

Gross Power (MW)
2 Comb. Turbines: 464 MW (total)
1 Steam Turbine: 230-275 MW

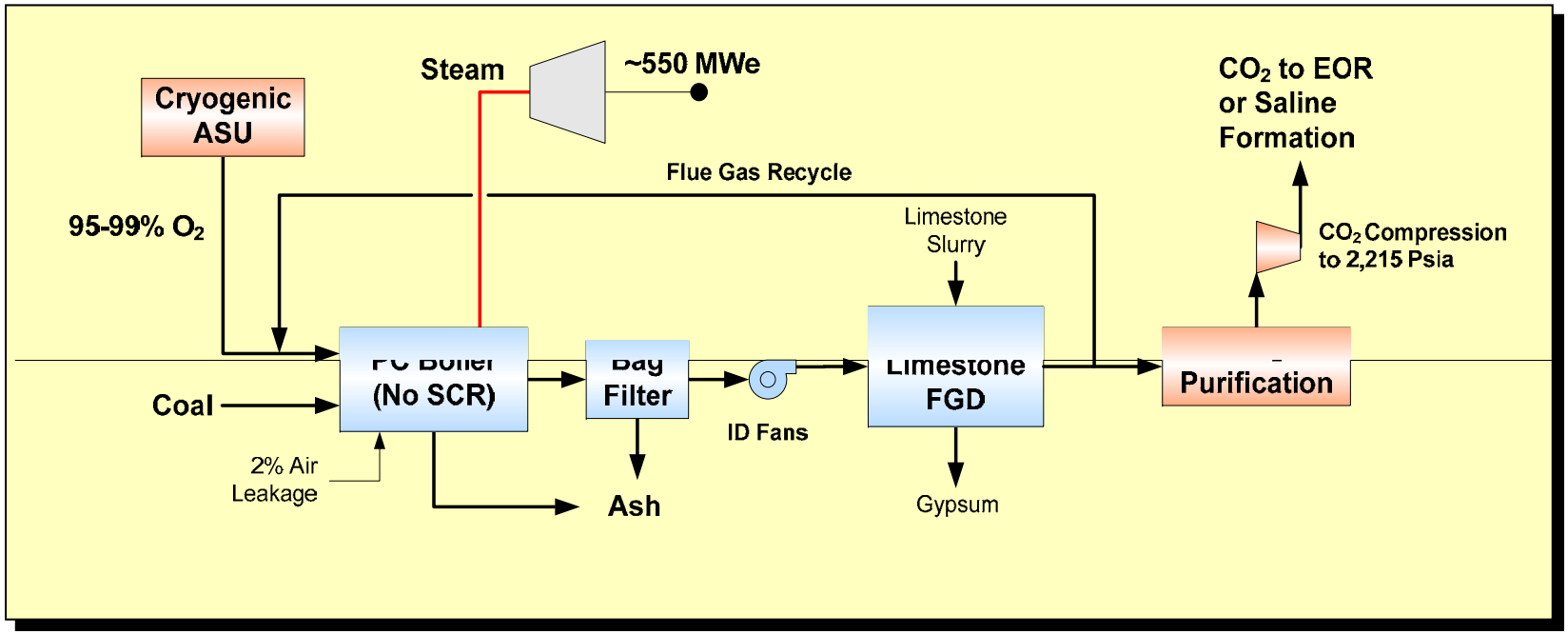
PC / Amine Scrubbing -- CO_2 Capture Cases



Design Assumptions:

1. 90% CO_2 Capture
2. Sulfur polishing step to maintain <10 ppm SO_2 into absorber
3. MEA regeneration steam is extracted from the IP/LP crossover pipe

PC / Cryogenic ASU Oxyfuel Combustion

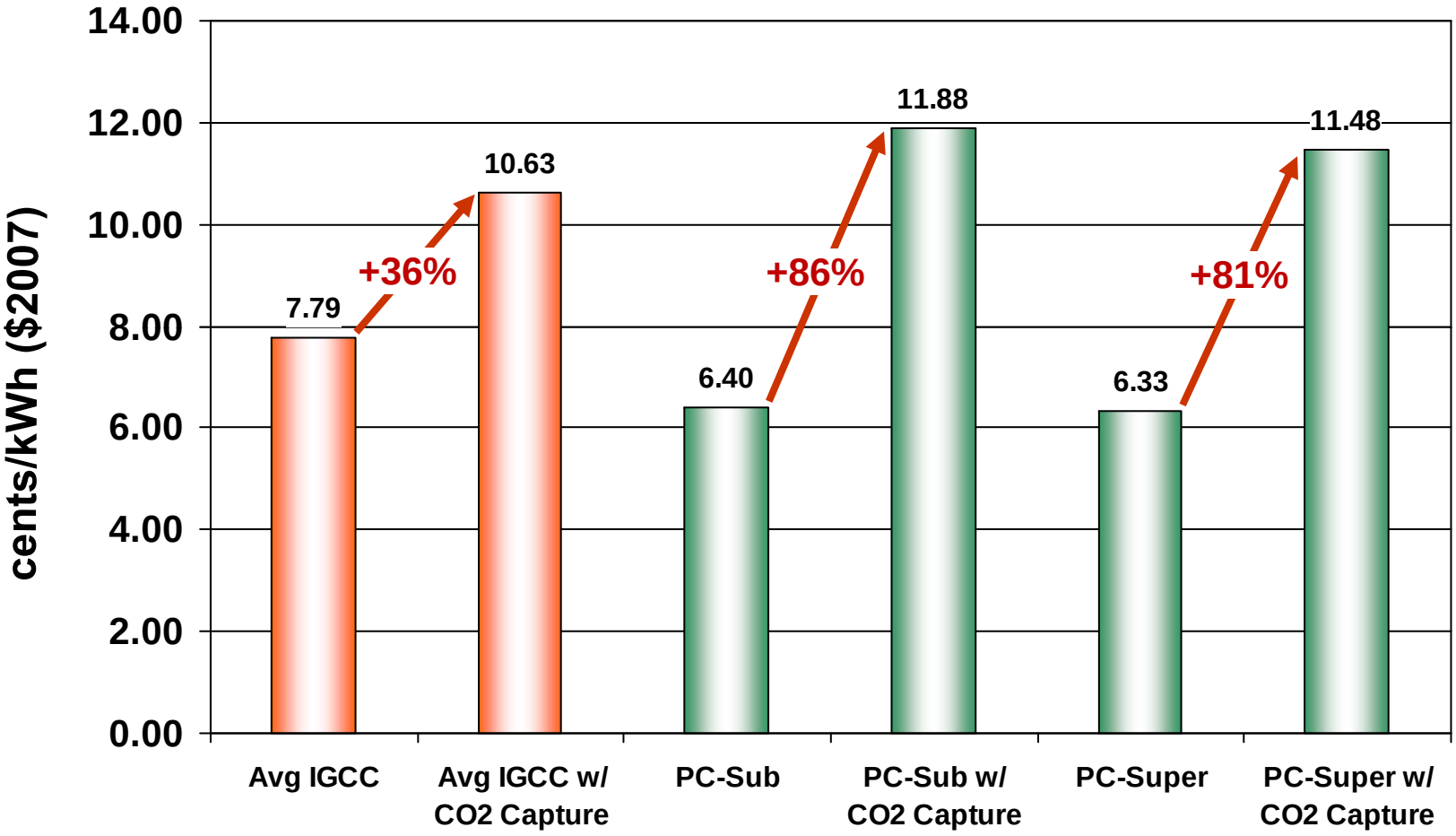


Evaluate:

1. Impact 95 versus 99% oxygen purity has on the CO_2 purification/compression process
2. Minimum CO_2 recycle rate
3. Co-sequestration (CO_2/NOx/SOx) feasibility

Cost of Electricity Comparison -- New Plants

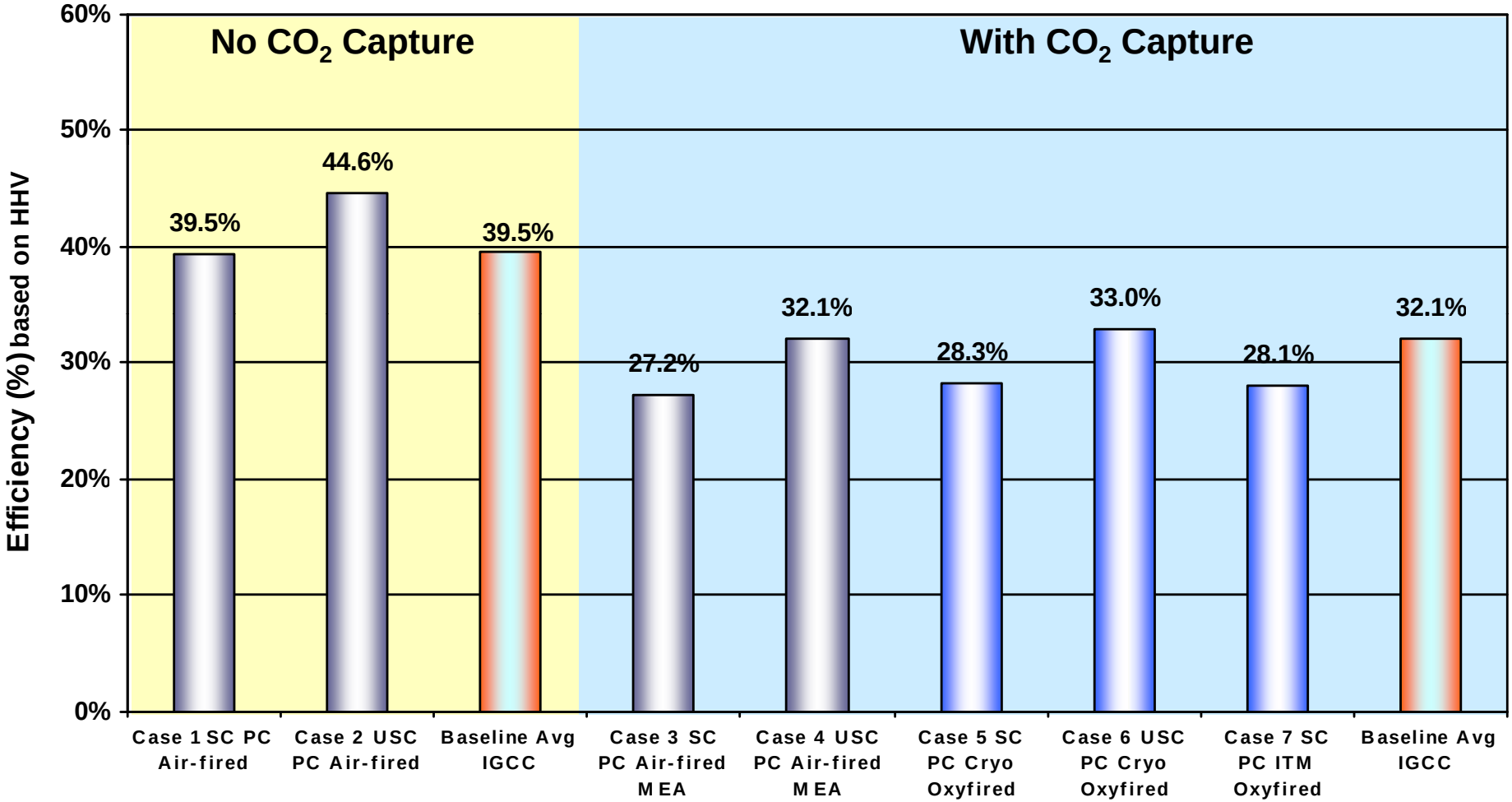
(Baseline Study)



January 2007 Dollars, Coal cost $1.80/$10^6$ Btu

DOE/NETL Report: "Cost and Performance Baseline for Fossil Energy Plants", May 2007

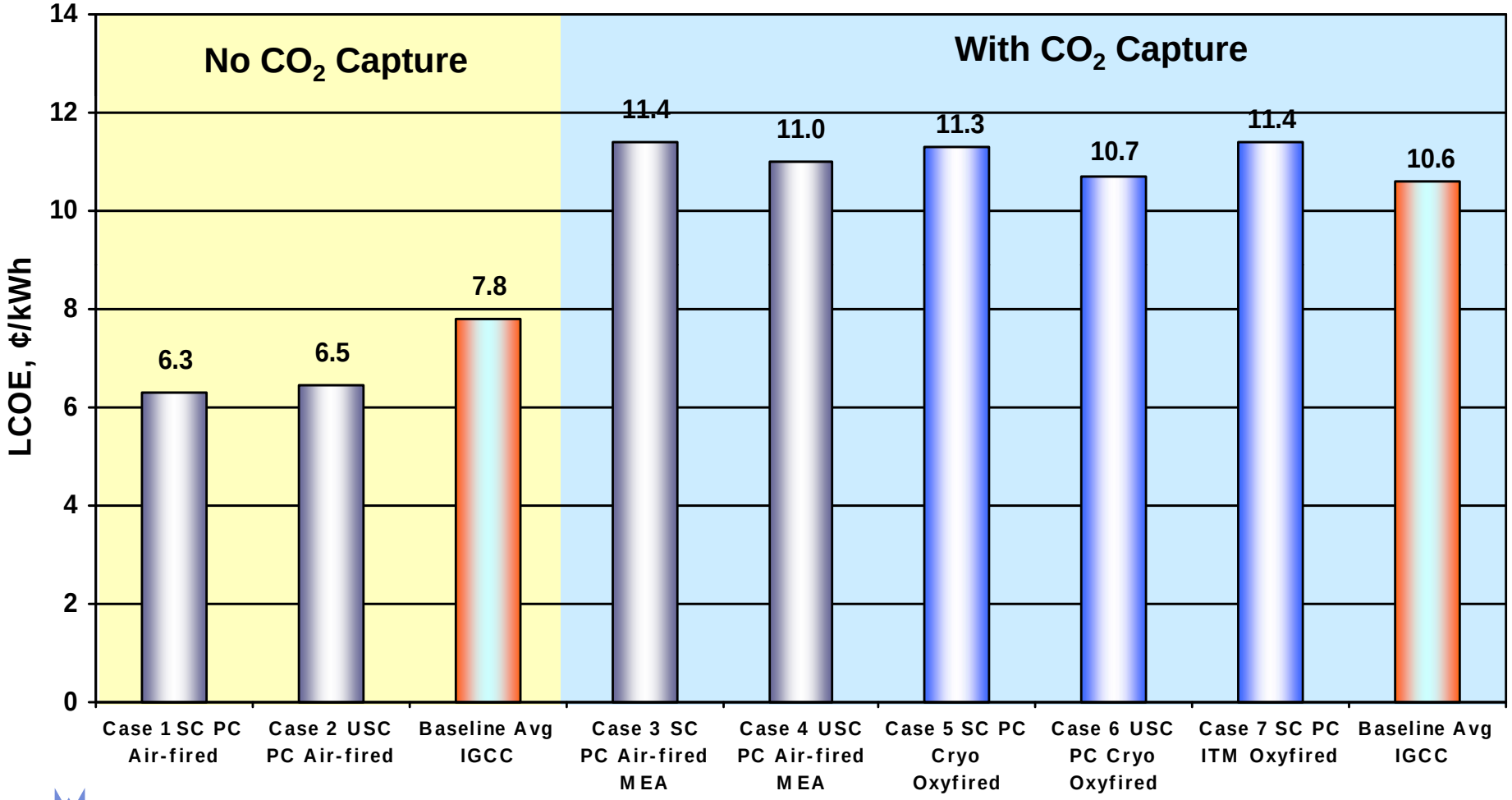
Efficiency Comparison



Supercritical (SC): 3,500 Psig/1,110°F/1,150°F (Current state-of-the-art)

Ultra-supercritical (USC): 4,000 Psig/1,350°F/1,400°F (Advanced Materials Program Target:2015—2020)

Levelized Cost of Electricity Comparison



Includes costs for CO_2 Transport, Storage, & Monitoring

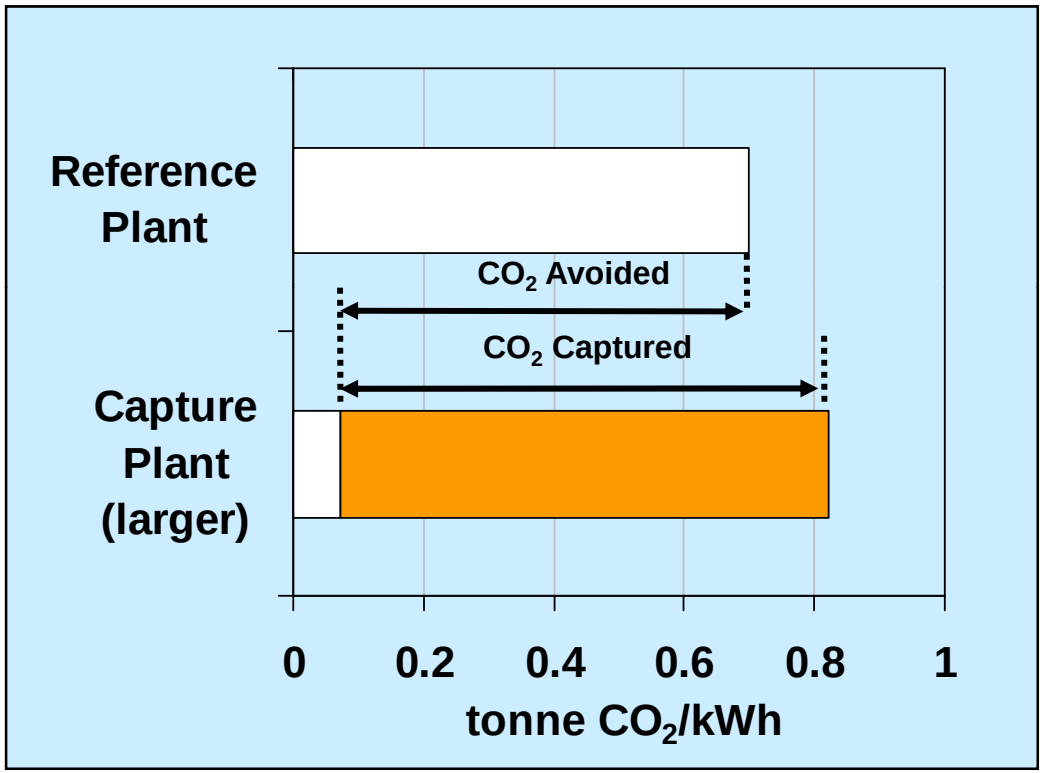
Calculating CO_2 Mitigation Costs

CO_2 Avoided

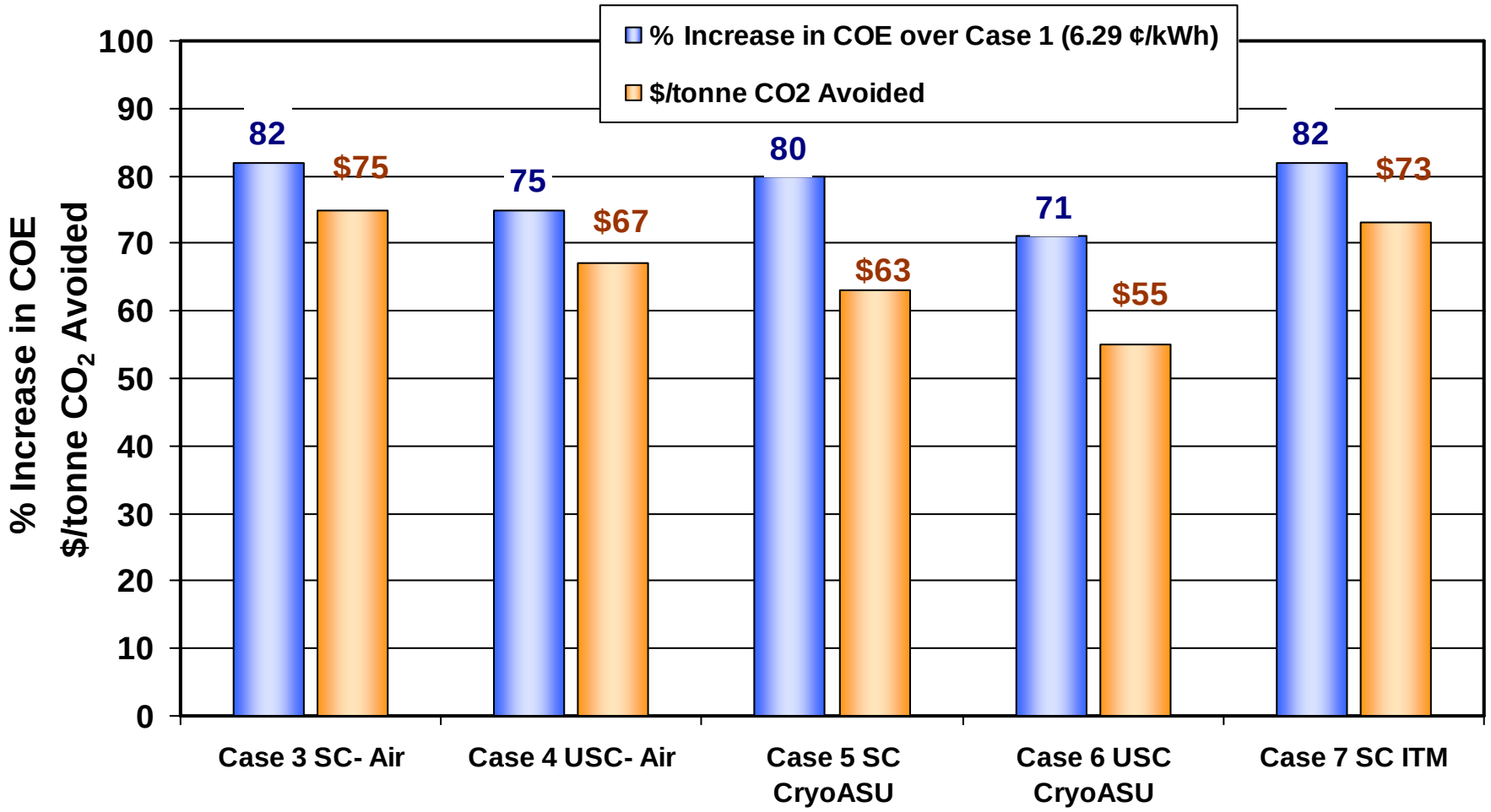
$$\frac{(COE_{capture} - COE_{base})}{(Emissions_{base} - Emissions_{capture})}$$

CO_2 Captured

$$\frac{(COE_{capture} - COE_{base})}{(CO_2\ Removed)}$$

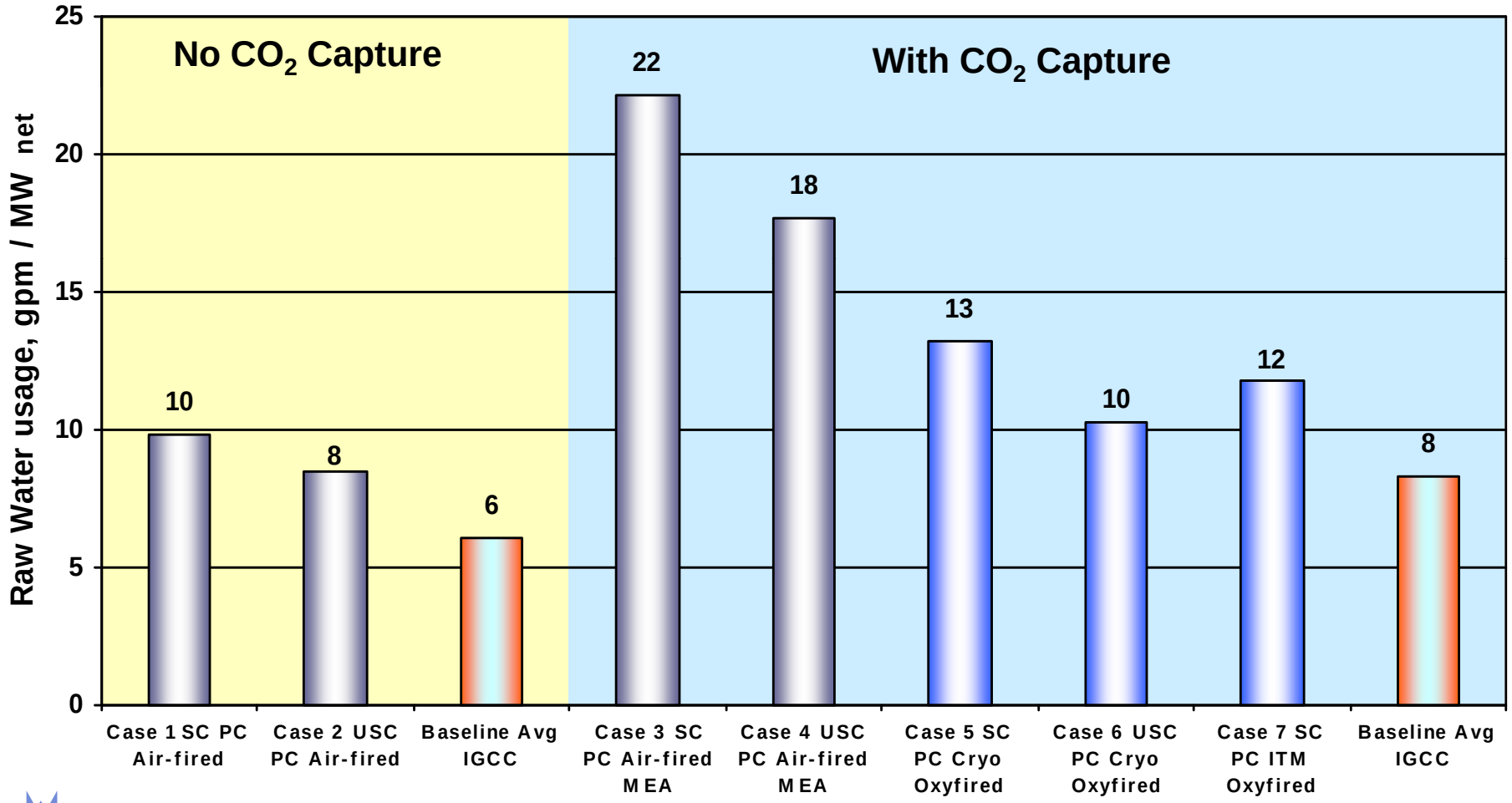


CO_2 Capture Mitigation Costs



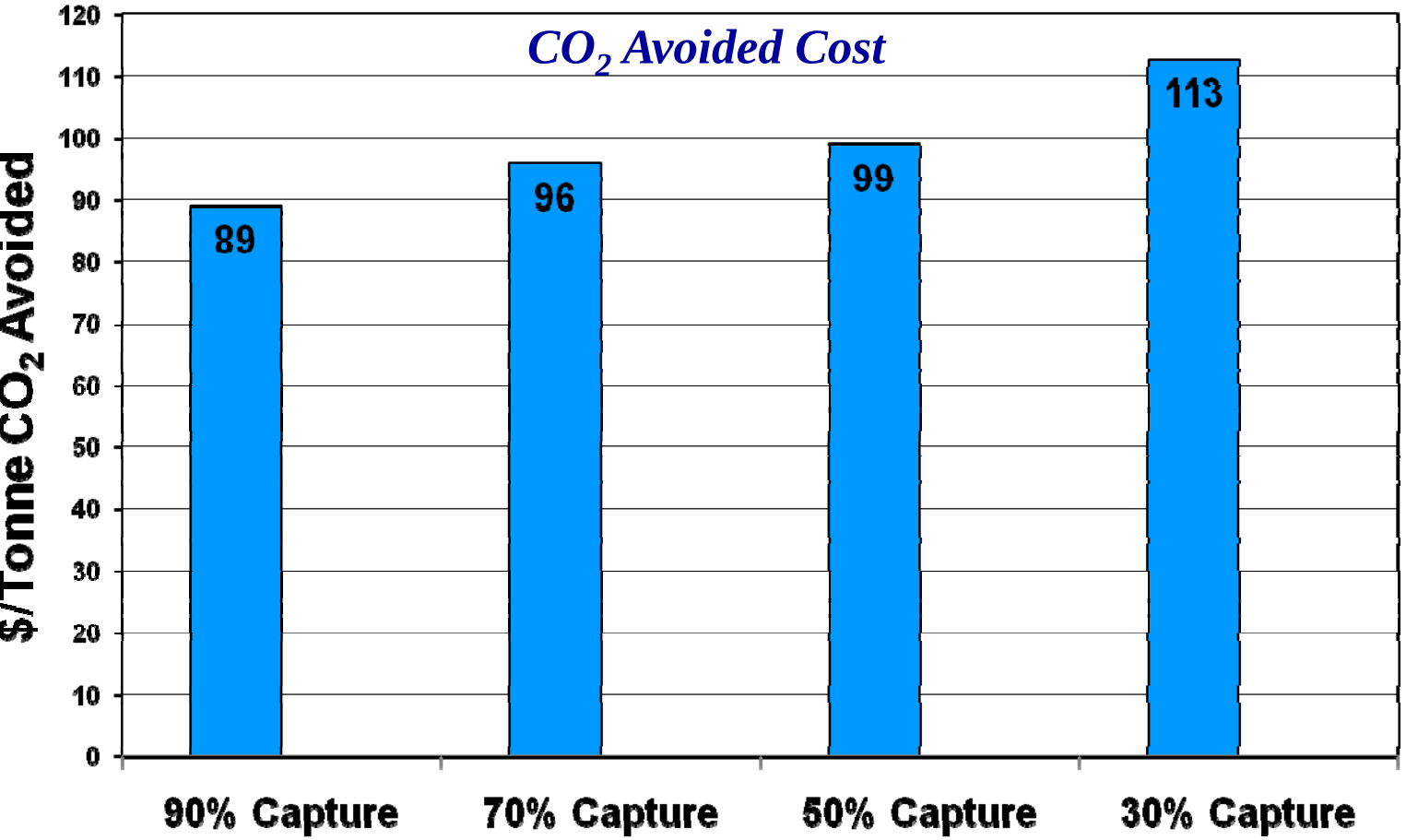
*Including CO_2 transport, storage and monitoring costs

Raw Water Usage per MW_{net} Comparison



rofit Study - Post-Combustion Amine CO_2 Scrubbing

AEP Conesville Unit #5, Subcritical, 463MWe (gross)



TL

Study Highlights: Efficiency & Capital Cost

- **Coal-based plants using today's technology are efficient and clean**
  - IGCC & PC: 39%, HHV (without capture on bituminous coal)
  - Meet or exceed current environmental requirements
  - Today's capture technology can remove 90% of CO_2, ***but at a significant increase in COE and decrease in efficiency***

- **Total Plant Cost: IGCC ~20% higher than PC capex**
  - PC: $1,600/kW (average)
  - IGCC: $1,900/kW (average)

- **Total Plant Cost with Capture: PC > IGCC capex**
  - IGCC: $2,500/kW (average)
  - PC (Amine): $2,900/kW (average)
  - PC (Oxyfuel): $2,900/kW

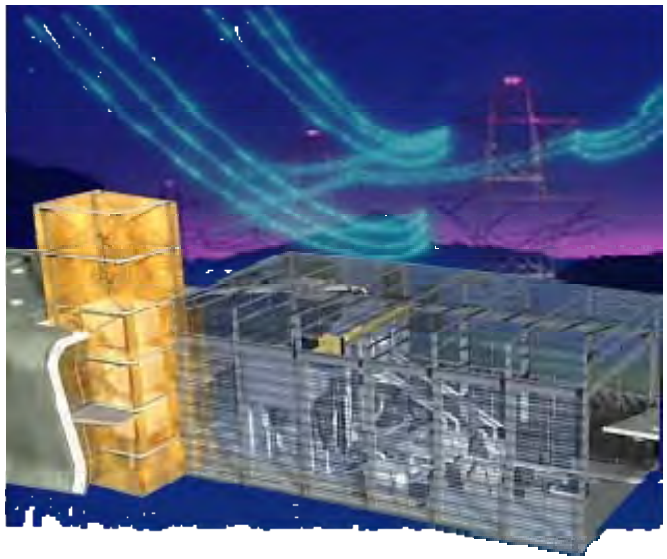
Study Highlights: COE

- **20 year levelized COE: PC lowest cost option**
  - PC: 6.4 ¢/kWh (average)
  - IGCC: 7.8 ¢/kWh (average)
- **With CCS: IGCC lowest cost option**
  - IGCC: 10.6 ¢/kWh (average)
  - PC (Amine): 11.4 ¢/kWh (average)
  - PC (Oxyfuel): 11.3 ¢/kWh

FutureGen

rld's first near zero-emission, full-scale al-based power plant to:

- **Co-produce electricity & H_2 from coal with IGCC**
- **Emit virtually no air pollutants**
- **Capture & permanently sequester CO_2 (1 million tonnes/yr)**
- **Integrate operations at full-scale (275 MWe) – a key step**



FutureGen Project

A billion-dollar, 10-year project to create the world's first coal-based, near-zero emission electricity plant with carbon capture and sequestration

Industry-led project

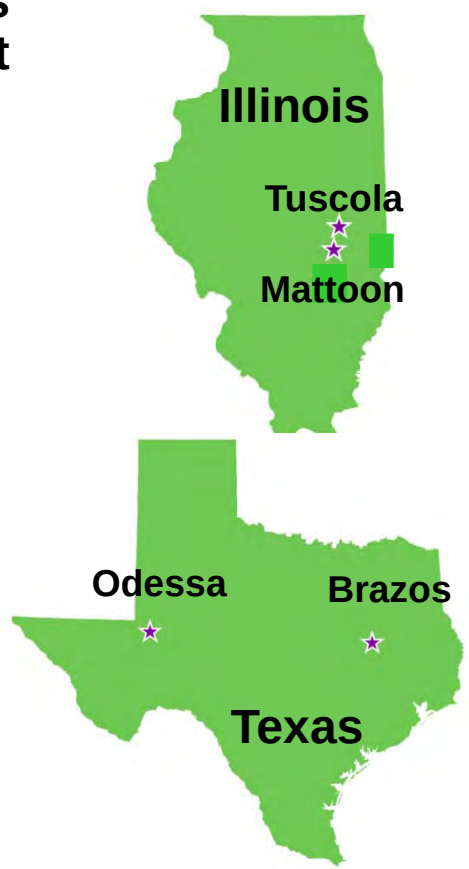
- Twelve leading companies with operations on six continents

Industry will choose project site & backbone technologies

- Down-selected to four potential sites

Government oversight and participation

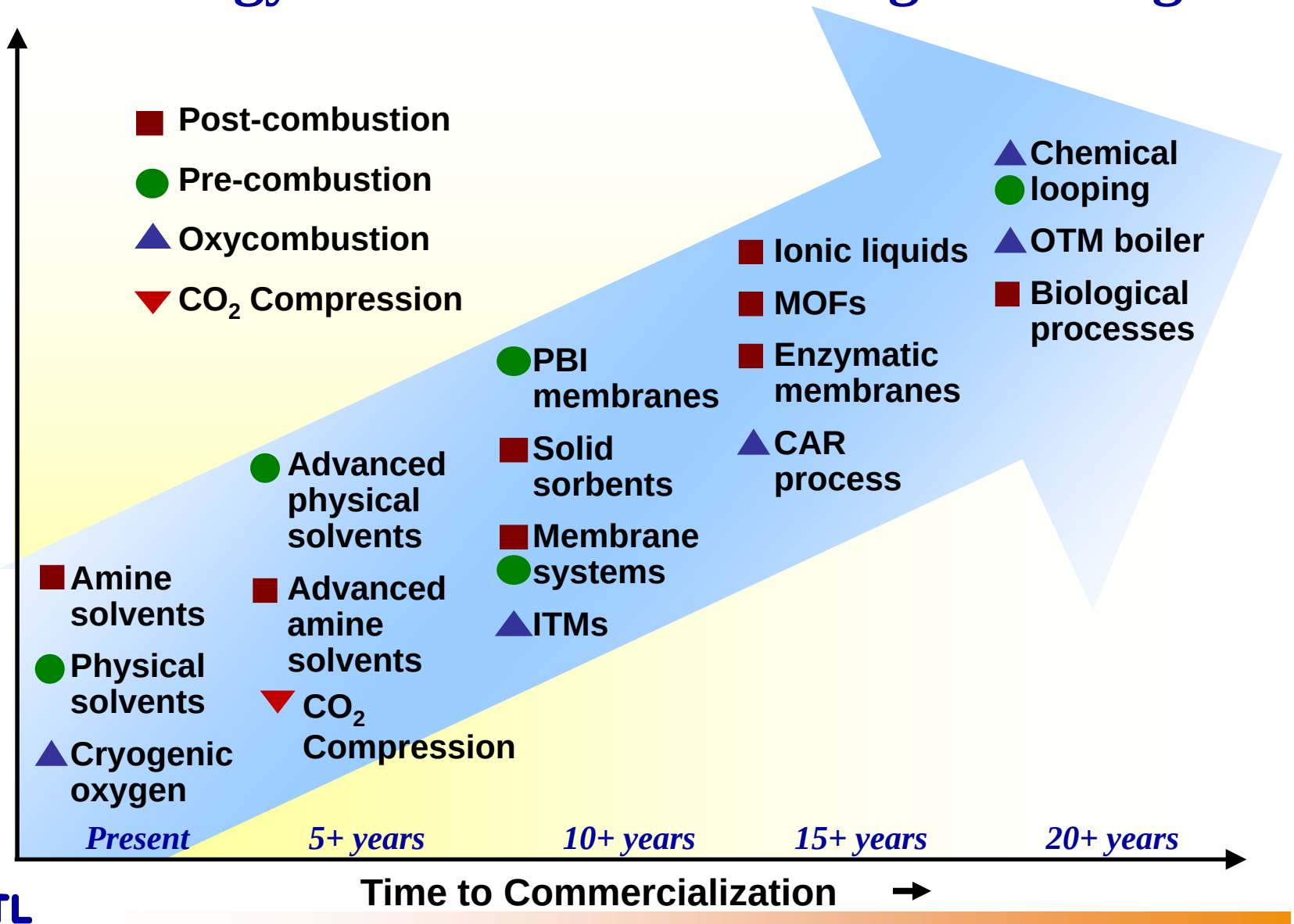
- United States, China, India, South Korea, Japan, Australia



FutureGen™ ALLIANCE

AEP · bhpbilliton · Peabody · xstrata coal · FOUNDATION COAL · 中国华能集团公司 CHINA HUANENG GROUP · RIO TINTO ENERGY AMERICA · ppl · SOUTHERN COMPANY Energy to Serve Your World℠ · CONSOL ENERGY · ANGLO AMERICAN · e·on U.S.

Technology Advances Are Starting to Emerge



Additional Observations

- **Technology is available today for carbon capture from new and retrofitted coal-fired IGCC and PC power plants, however:**
  - It is expensive
  - Parasitic load is high
  - Reliability needs to be proven
- **Sequestration needs to be adequately demonstrated, especially in deep saline reservoirs with large-volume CO_2 injection**
- **DOE RD&D program is targeting the key issues**
  - Lower cost, advanced technology (R&D program)
  - Proving sequestration (sequestration program, Regional Partnerships)
  - Integration (FutureGen, CCPI)

For Additional Information

NETL
www.netl.doe.gov

Office of Fossil Energy
www.fe.doe.gov

FutureGen Alliance
www.futuregenalliance.org/

Joe Strakey

412-386-6124

joseph.strakey@netl.doe.gov