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Advanced Coal Workshop for EPA

IGCC – Status, Comparisons, and R&D
Other Advanced Coal Options
CO_2 Capture and Storage
Industry / EPRI Programs to Advance Deployment

Hank Courtright
Senior Vice President
June 19, 2006 Conference Call

Types of Coal Generation

- **Pulverized coal** (PC): Finely ground coal is burned to make steam and then flue gases are cleaned up; there are more than 1000 such “conventional coal” plants in the U.S.
- **Very high-temperature versions of PC** employ supercritical (SC) steam, and even higher use ultra-supercritical (USC)
- **Circulating fluidized-bed combustion** (CFBC or FBC): Larger coal pieces are “fluidized” by combustion air and entrained with a “sorbent” such as limestone to remove SO_2
- **Gasification** of coal involves reaction with oxygen and heat/ steam to produce a “synthesis gas” containing CO, hydrogen, and (sometimes) methane. The gas is cleaned and then burned in gas turbine with the exhaust heat used to make steam; such plants are “integrated gasification combined cycle” (IGCC).

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What Is "Clean Coal?"

- Even modern conventional coal plants are much cleaner than prior designs, but most people refer to designs meeting very stringent emission regulations as "clean coal"
- Coal-based IGCC plants have very low SO_2, NOx and mercury emissions and are almost as clean as natural gas plants
- Advanced PC combustion plants designs have improved efficiency and low emissions
- EPRI and the Coal Utilization Research Council have defined clean coal plant performance and emission goals for 2010 and 2020 (see Roadmap at www.coal.org). DOE has provided significant input into the Roadmap.

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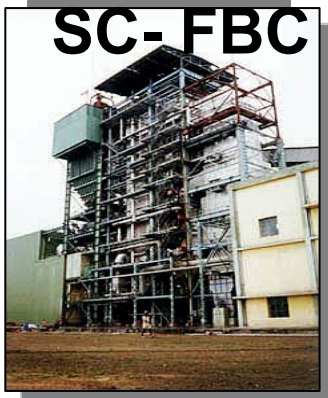
Regional U.S. Coal Differences Favor Multiple Advanced Coal Options



- IGCC with slurry feed economics are best with "high-rank" bituminous coals or low-rank (PRB) coal plus petroleum coke (economics currently do not favor IGCC, but emissions do)
- New IGCC designs may be better for low-rank coal – these are still in developmental
- Waste coals and biomass may be best in fluidized-bed combustion (FBC) units, but supercritical steam conditions are unproven
- Most announced new U.S. coal plants are for new "conventional" pulverized coal due to lower fuel costs; where fuel costs are high, ultra-supercritical (USC) designs are favored
- CO_2 can change the balance

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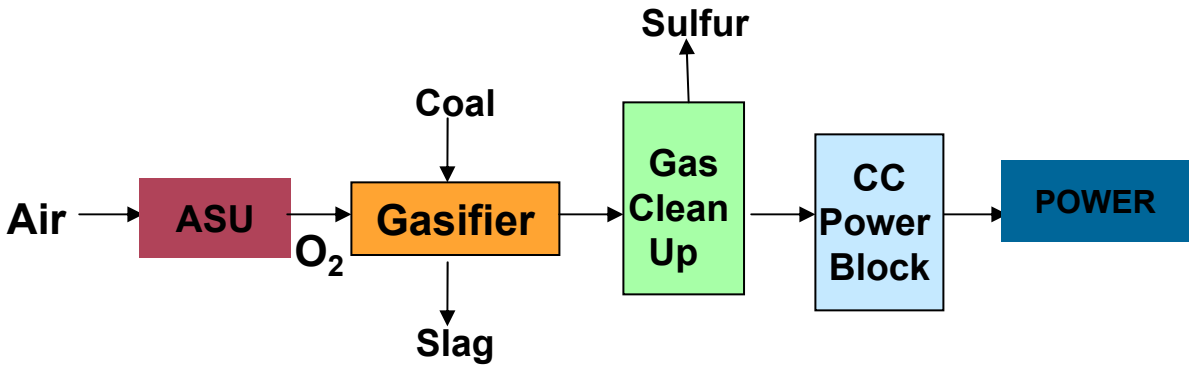
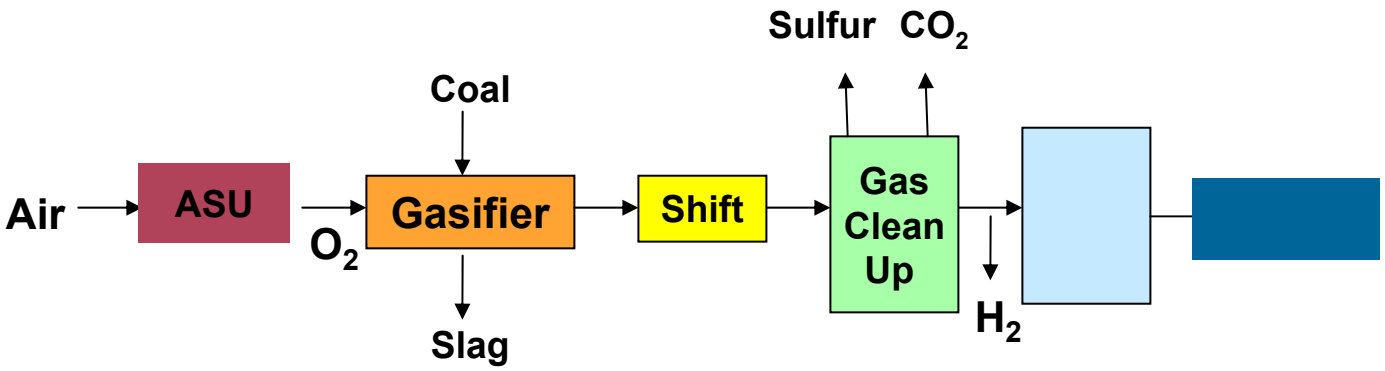
IGCC With and Without CO_2 Removal



IGCC



H_2 & CO_2 (e.g., FutureGen, BP Carson on Coke)

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Today - Existing Coal-based IGCCs

Puertollano (Spain)

Wabash (Indiana)

Polk (Florida)

Buggenum (Netherlands)

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Coal Based IGCC Plants

Project/ Location	Combustion Turbine	Gasification Technology	Net Output MW	Start-Up Date
Wabash River, IN	GE 7 FA	E Gas (ConocoPhillips)	262	Oct 1995
Tampa Electric, FL	GE 7 FA	Texaco (GE Energy)	250	Sept 1996
Nuon (Formerly Demkolec) Buggenum Netherlands	Siemens V 94.2	Shell (Offered jointly with Krupp-Uhde)	253	Jan 1994
ELCOGAS Puertollano Spain	Siemens V 94.3	Prenflo (Offered jointly with Shell)	300	Dec 1997

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US IGCC/Gasification (Some Projects in Development)

Name/Owner	Location	MW	Technology	Other Products	Notes/Status
AEP	OH, W.Va, Ky	600	GE		FEED w/GE
Cinergy	IN	600	GE		FEED w/GE
Excelsior	Mesaba, MN	600	COP E-Gas		CCPI 2
Steelhead	Illinois	615	COP E-Gas	95 MSCFD SNG	FEED
Energy NorthWest	Washington	600			Study with COP E-Gas
WMPI	Pennsylvania	60	Shell	5000 bpd F-T Diesel	CCPI 1, Culm (waste coal)
SoCo/Orlando	Florida	285	Air-blown KBR		CCPI 2, PRB
Royster Clark/Rentech	Illinois	60	COP E-Gas	1000 tpd NH3 2000 bpd F-T	FEED
ERORA	Illinois	550	GE	Chemicals?	FEED Eastman
BP/Edison Mission	California	500		Hydrogen. CO_2 for EOR	Pet Coke Announcement
Global	Lima, OH	530	COP E-Gas		Earth moving

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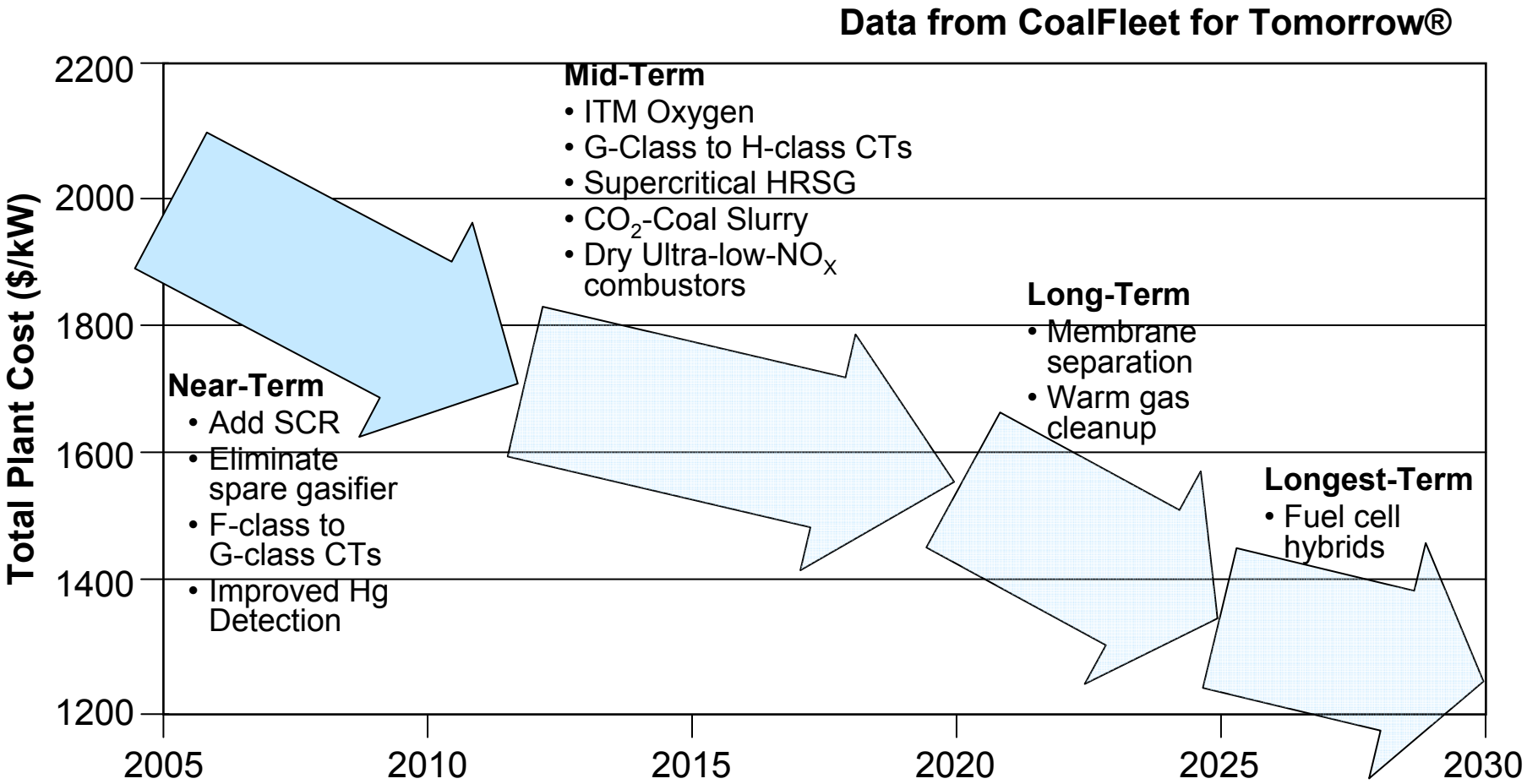
IGCC RD&D Implementation Path for Cost Reduction Case:
Slurry-fed gasifier, Pittsburgh #8 coal, 90% availability, 90% CO_2 capture, 2Q 2005 dollars



…plus efficiency also improves from 30–45%

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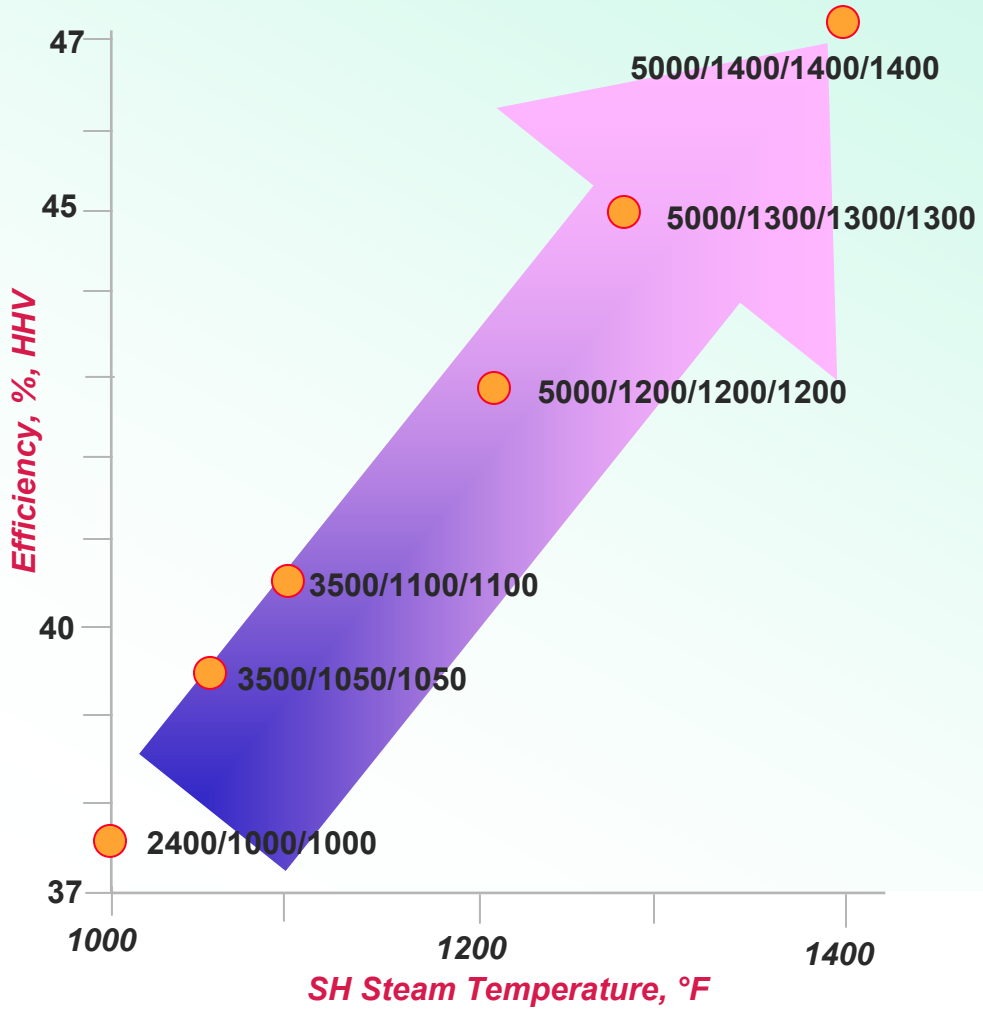
Ultrasupercritical PC Plants



- **European and Japanese USC PC Experience Base**
  - 600°C (1112°F) high availability, good load following
  - Baseline S-O-A for a new coal-fired plant
- **In Development:**
  - European Advanced 700°C PC (1292°F)
  - *DOE EIO/EPRI 760°C (1400°F) boiler materials program*

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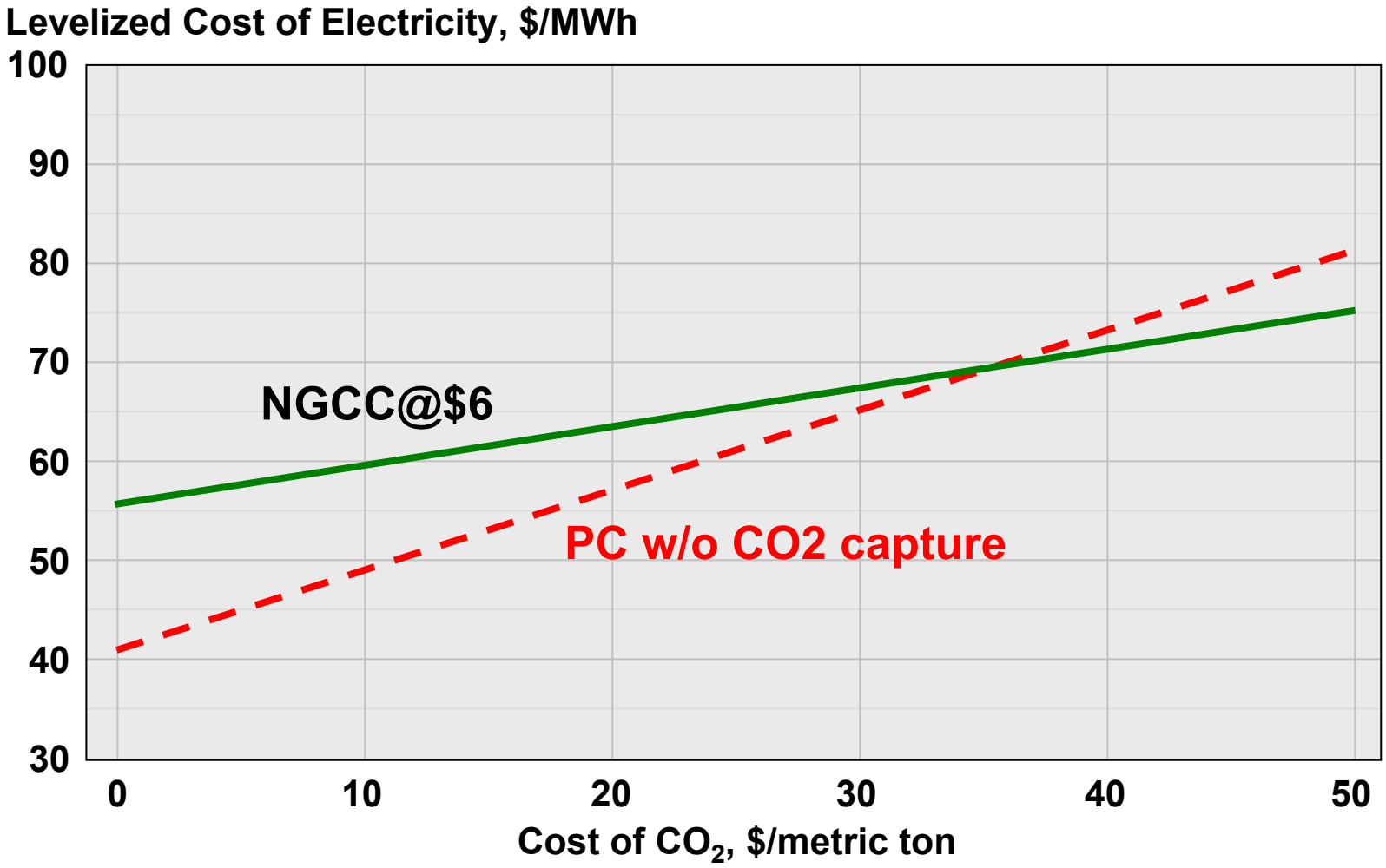
Comparative Costs of 2010 Generating Options



EPRI 2004 projections for Midwest site and Pittsburgh #8 Bituminous coal @ 80% CF

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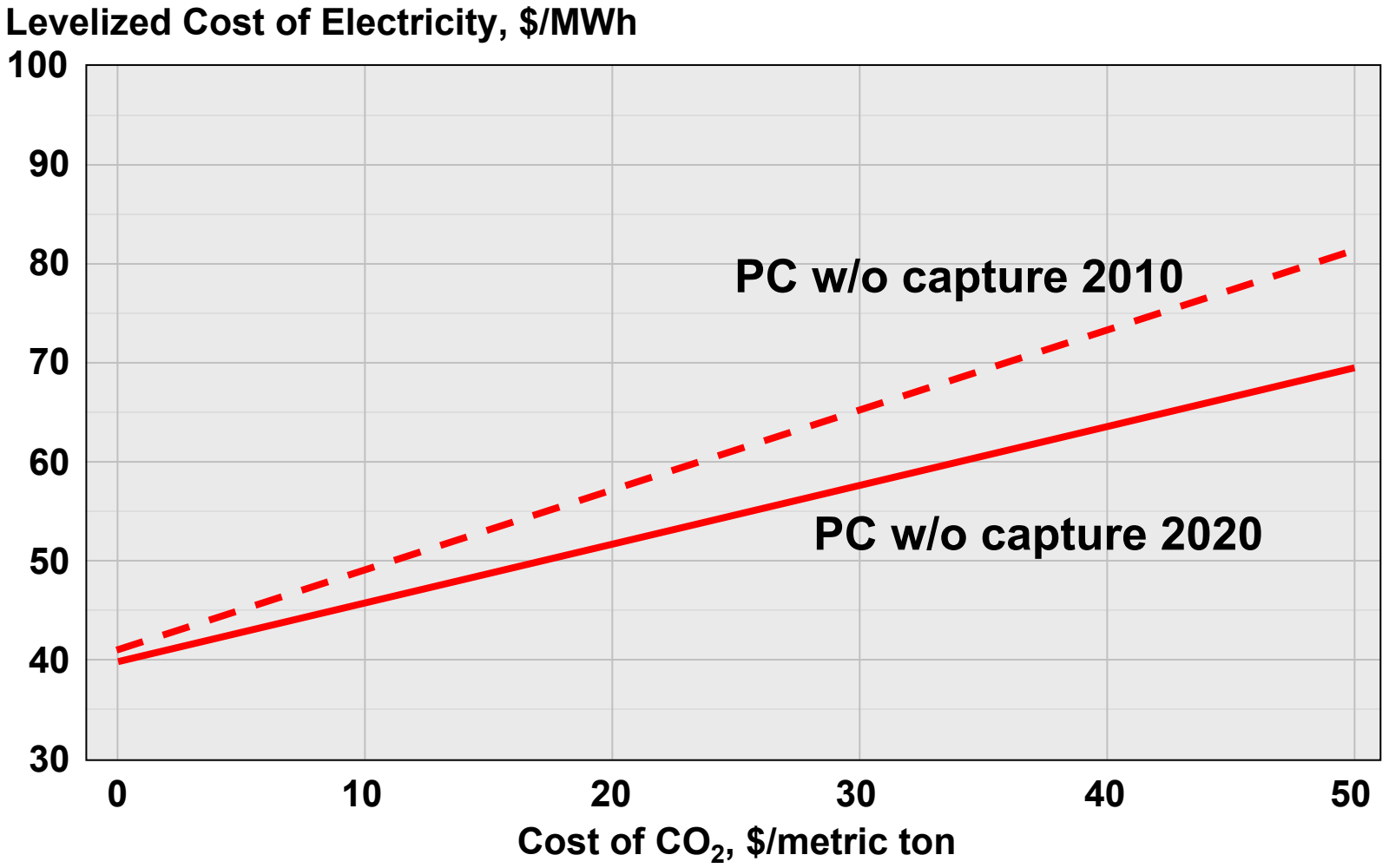
Pulverized Coal w/o Capture



EPRI 2004 projections for Midwest site and Pittsburgh #8 Bituminous coal

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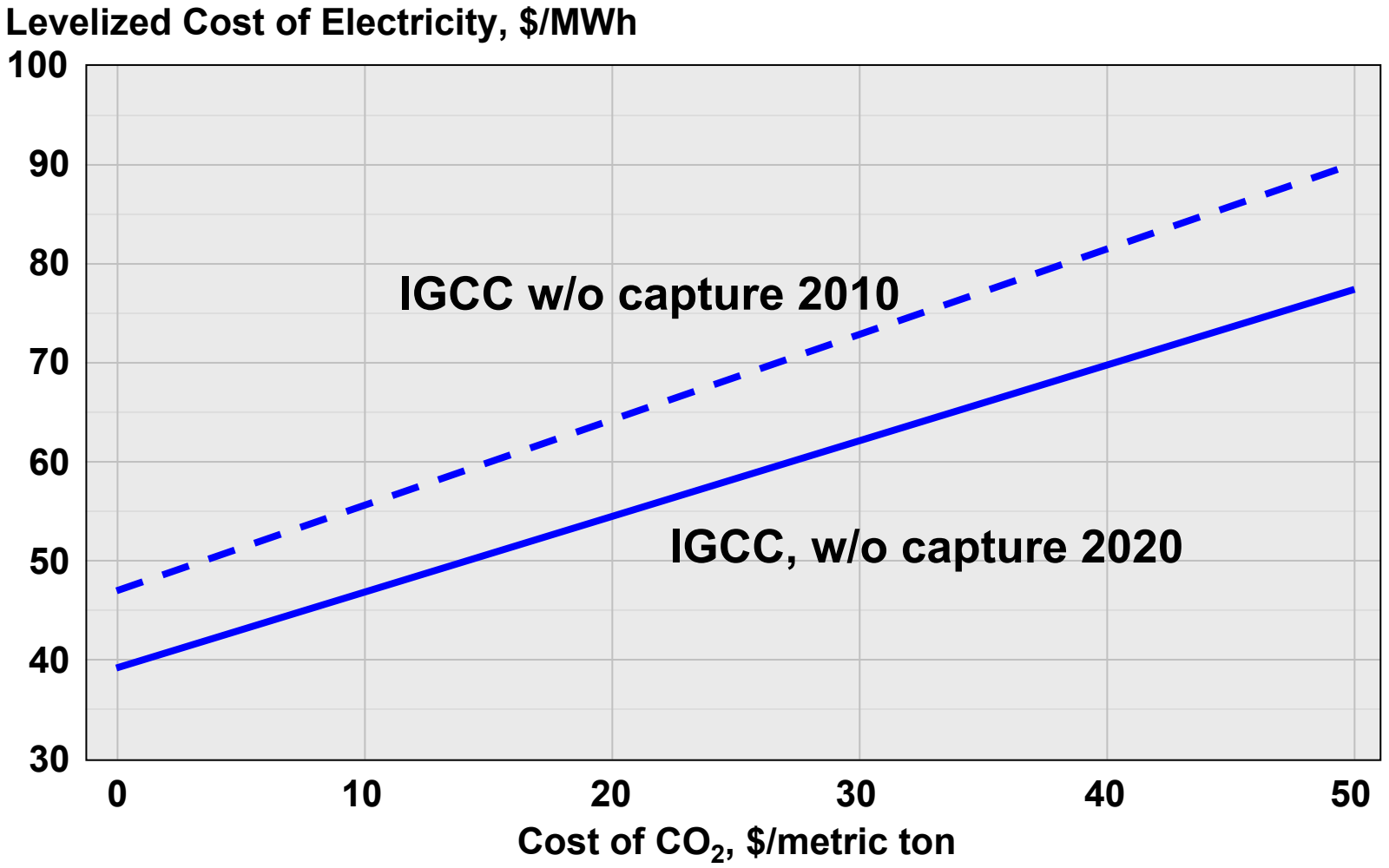
IGCC w/o Capture



EPRI 2004 projections for Midwest site and Pittsburgh #8 Bituminous coal

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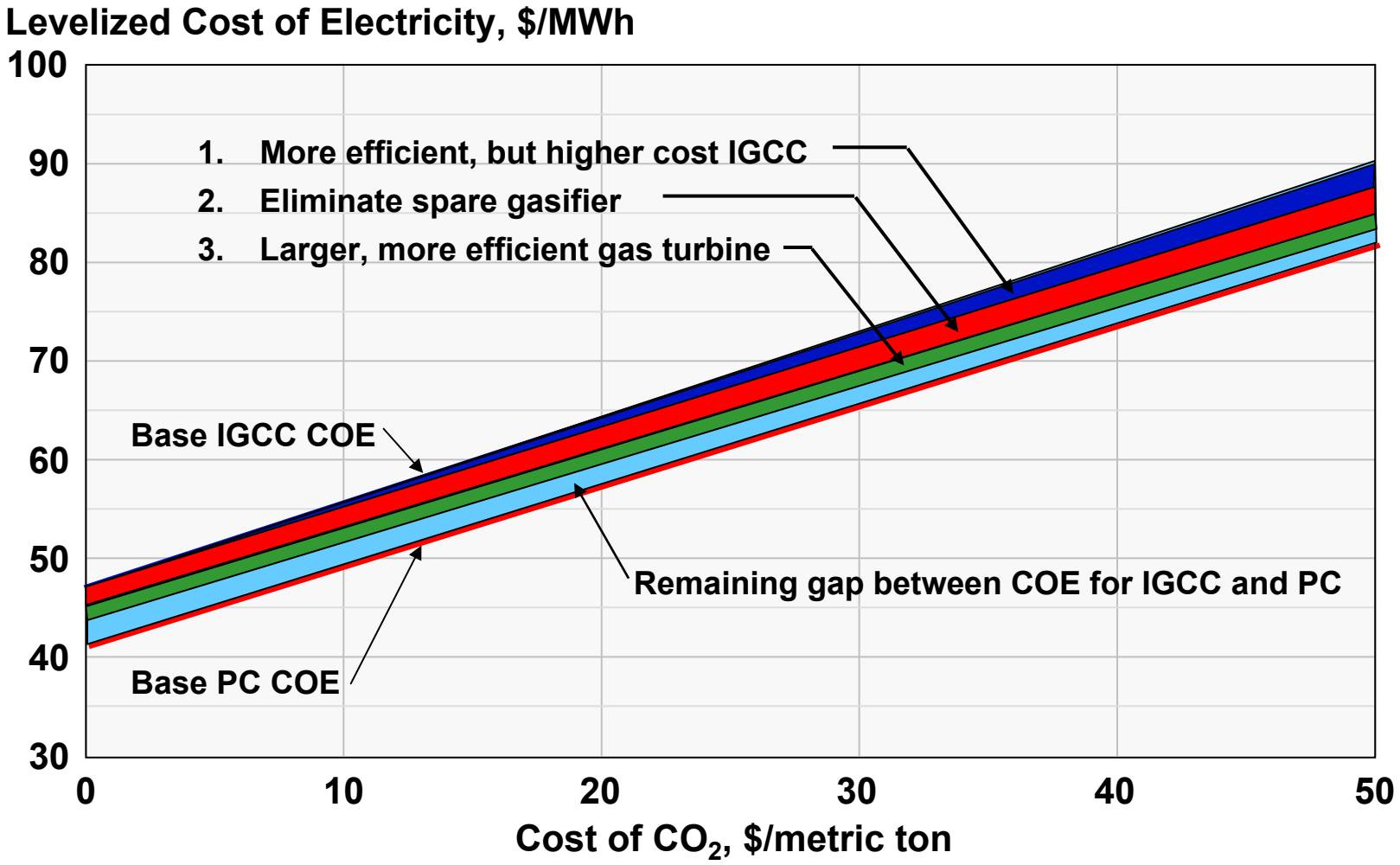
PC vs. IGCC with Improvements



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What About CO_2?

- Higher efficiency designs inherently produce less CO_2 per kWh
- **Neither IGCC nor pulverized coal inherently captures CO_2 and it takes additional energy and cost to capture and store CO_2**
- US and world efforts are aimed at developing better options for high efficiency generation and understanding how to economically capture and safely store CO_2
- CO_2 storage viability is key

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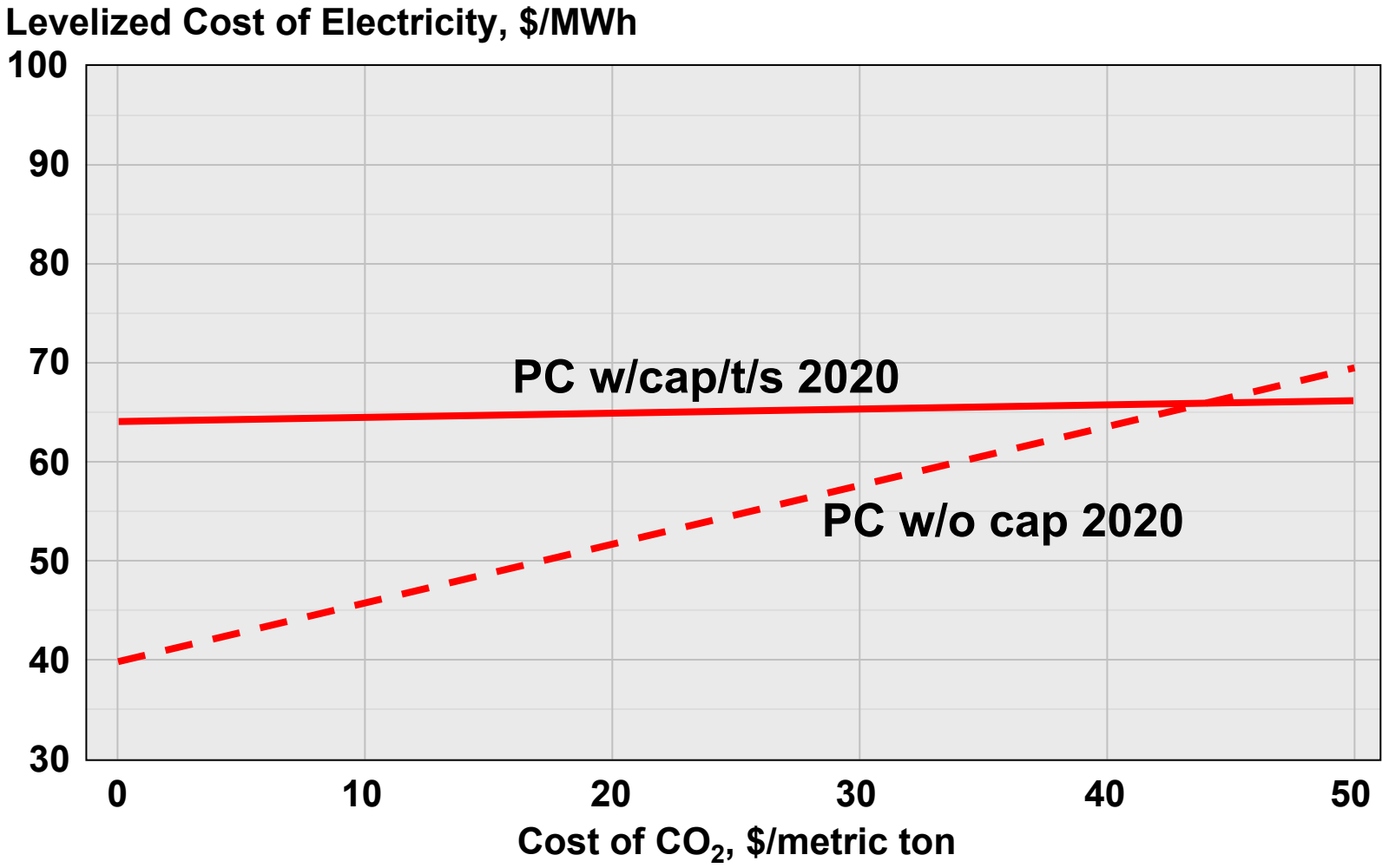
PC with capture/transport/storage



EPRI 2004 projections for Midwest site and Pittsburgh #8 Bituminous coal

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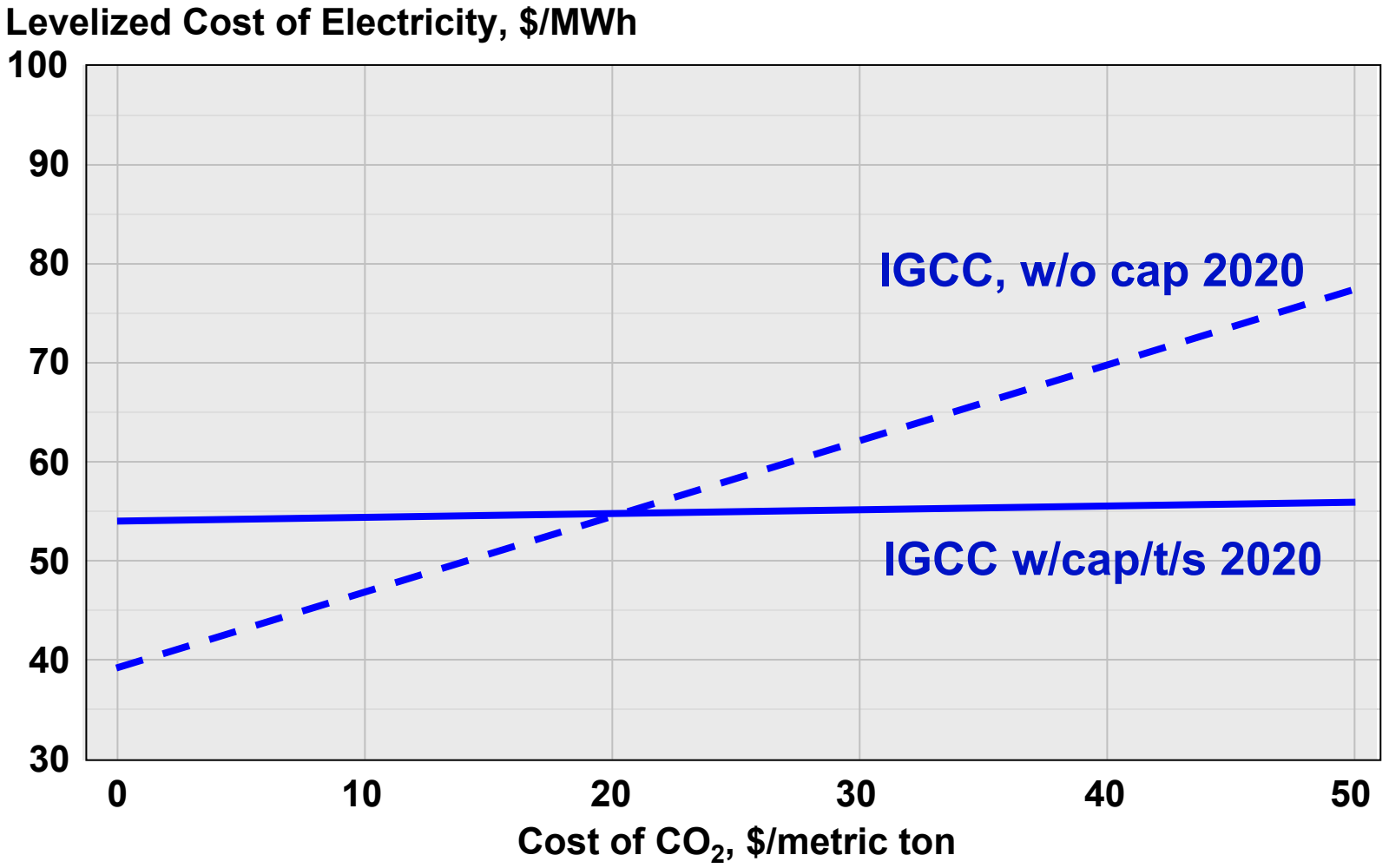
IGCC with capture/transport/storage



EPRI 2004 projections for Midwest site and Pittsburgh #8 Bituminous coal

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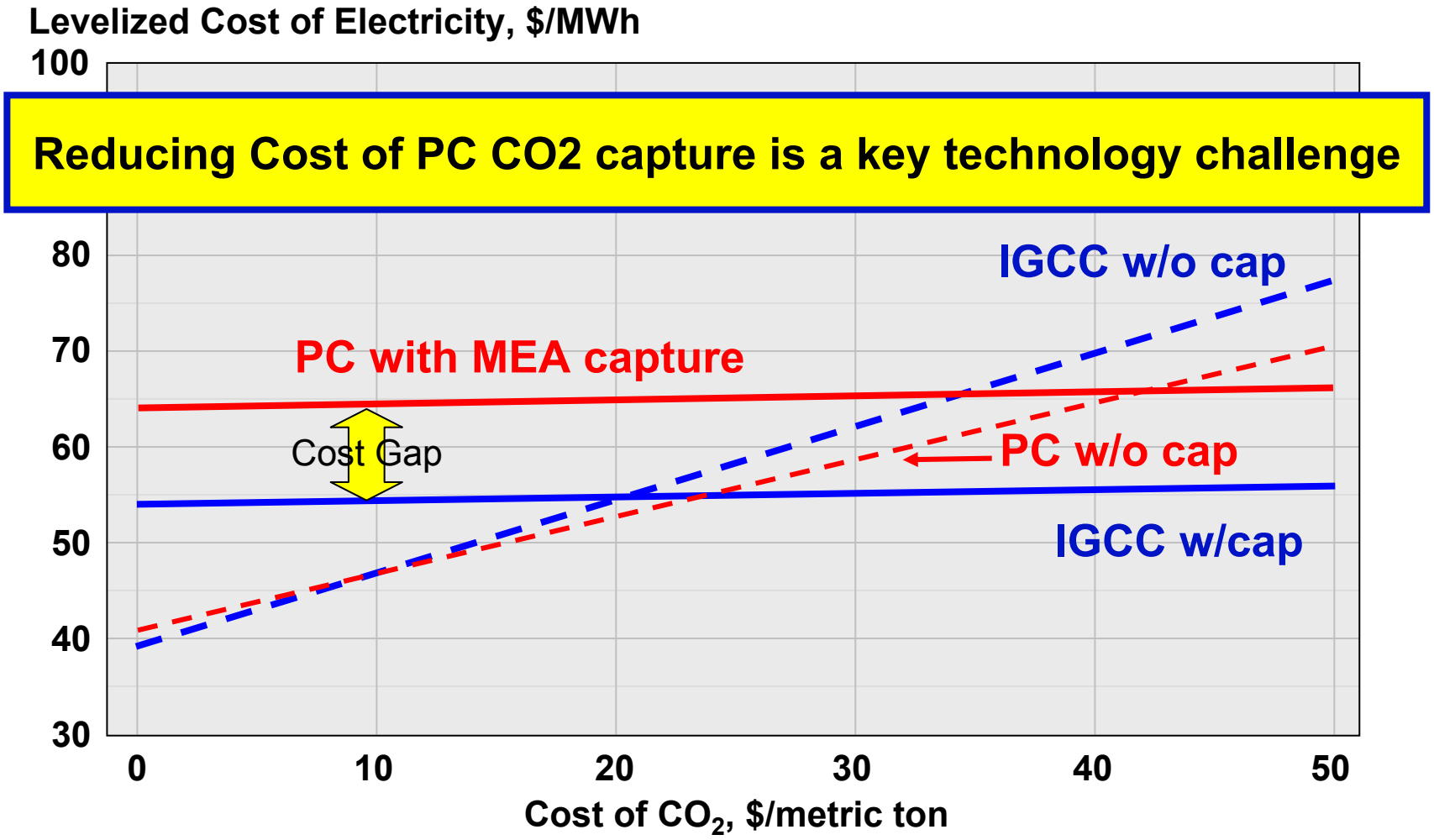
Comparison of IGCC and PC (2020)



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Overview of Advanced Coal R&D Programs

- **DOE Gasification and CO2 programs - extensive R&D&D**
- **FutureGen Alliance (DOE/Industry)**
  - A "living laboratory" for advancing IGCC technology and associated CO_2 capture technology and hydrogen co-production
  - Demonstration of large-scale storage of "gasification power plant" CO_2
- **EPRI CoalFleet Program**
  - Focused on accelerating the deployment of advanced coal technologies
    - IGCC
    - Ultra-supercritical PC
    - Supercritical Circulating Fluidized-Bed
  - Development of IGCC CO_2 capture capability/convertibility
- **EPRI CO_2 Capture Initiative**
  - Focused on developing advanced post-combustion CO_2 capture technology for PC plants
  - Understanding issues and demonstrating storage of CO_2 from combustion

Coordinated Plan Avoids Duplication and Gaps

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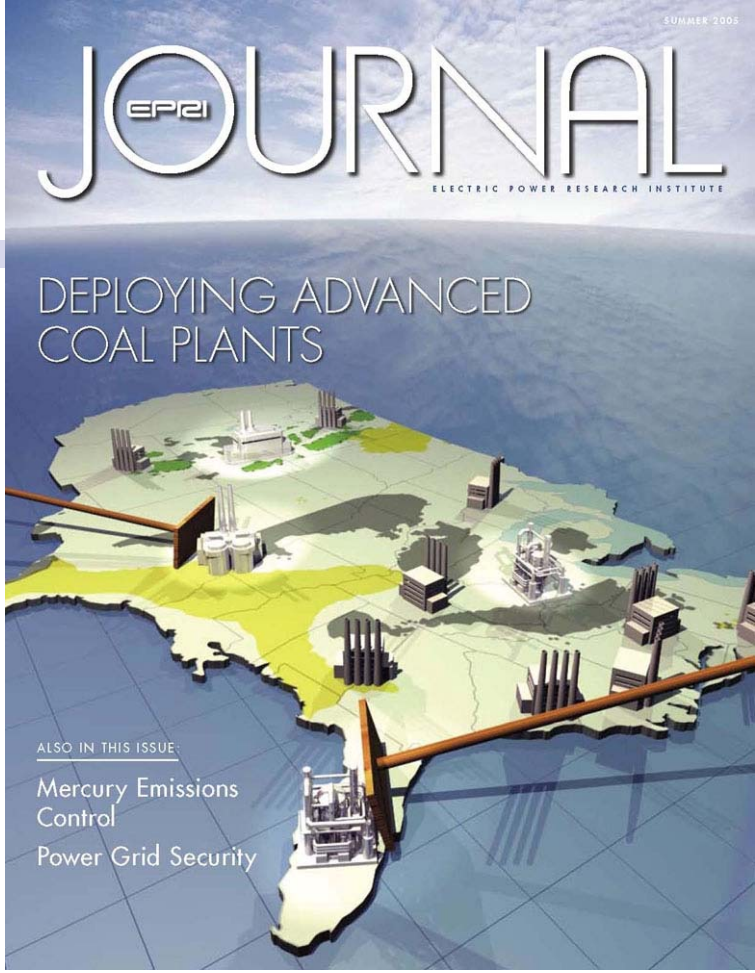
CoalFleet for Tomorrow® an EPRI Program

- An Industry Initiative to Accelerate the Deployment of Advanced Coal-Based Power Plants
- Billion Dollar Plus Investments in an Emission-Limited World
- Risks and questions IGCC & USCPC and other technology
  - Is it reliable?
  - What designs are best?
  - How can it be licensed (permits)?
  - How much will the new technology cost?
  - How can it be financed?
  - How can it be made CO_2 capture ready?



Summer 2005 EPRI Journal article available at www.EPRI.COM

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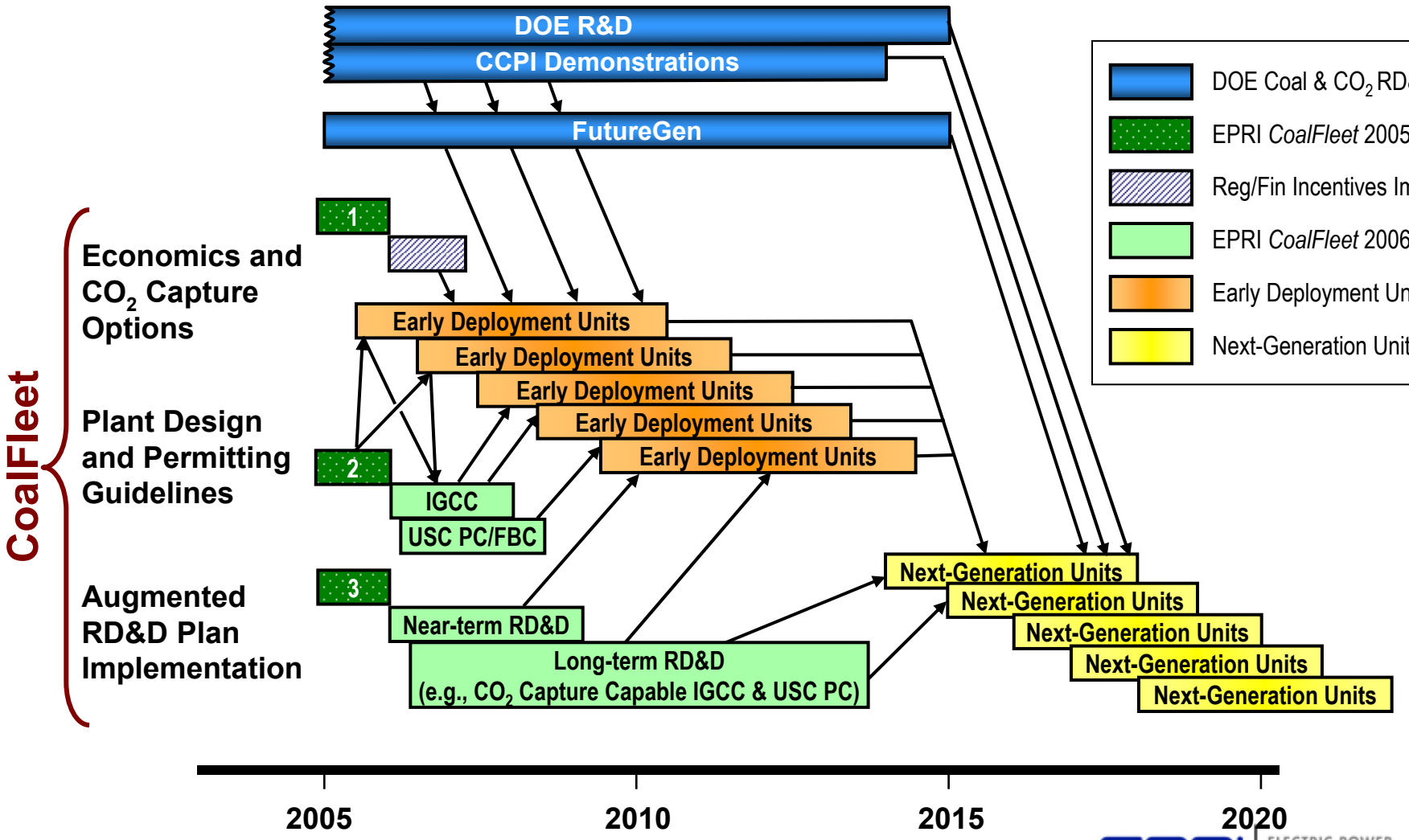
CoalFleet Leverages U.S. DOE/Industry Programs to Accelerate Deployment of Advanced Coal Plants



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Conclusions

- IGCC is a promising technology with very low emissions, excellent promised efficiency . IGCC has potential for capturing CO_2 with additional cost and some loss of efficiency – right now it is more expensive (10-15%) than pulverized coal without capture
- EPRI believes with western coals both IGCC and pulverized coal with CO_2 capture may be in competition regarding cost, emissions in 2015-2020.
- Major programs such as the DOE Regional Carbon Sequestration Partnerships promise CO_2 storage assurance
- FutureGen Program aimed at providing hydrogen firing plus CO_2 capture and storage – a living laboratory
- CoalFleet for Tomorrow® is aimed at deployment of the best designs using global lessons learned with CO_2 options for capture

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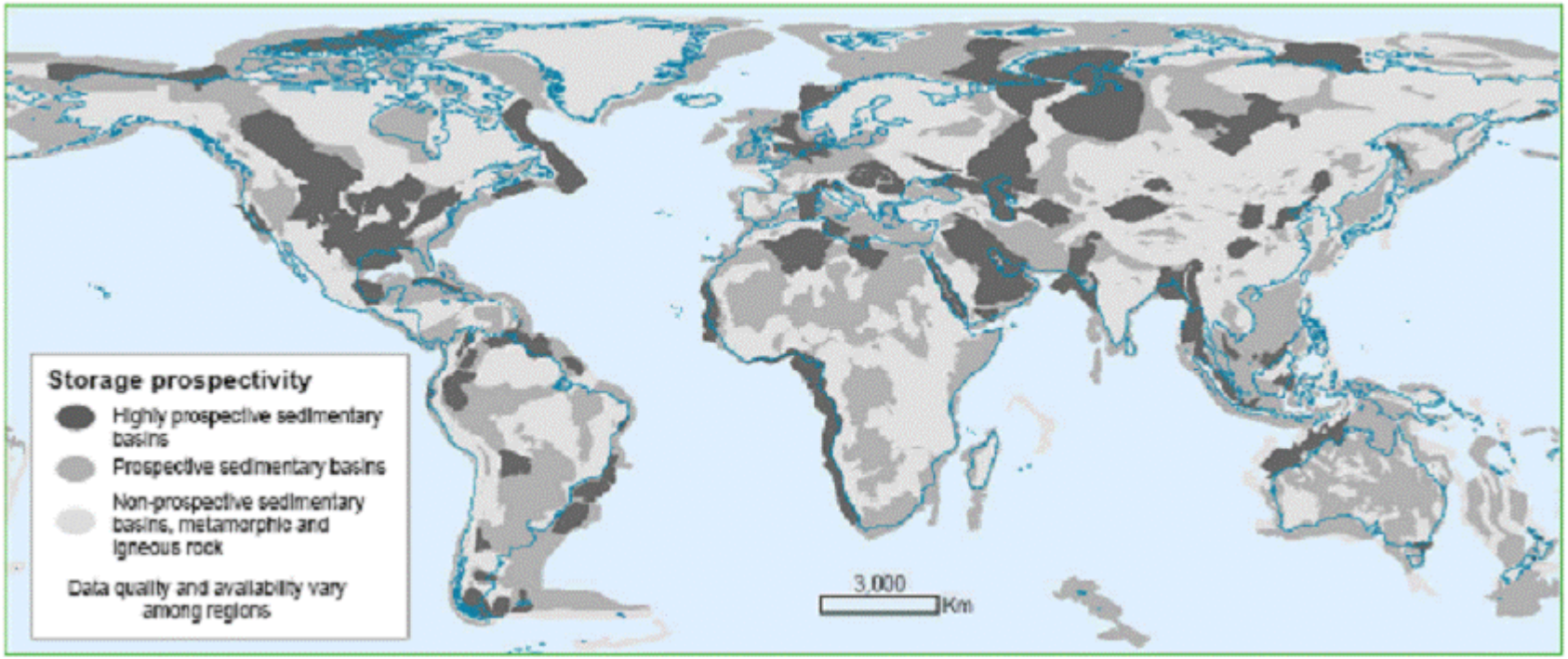
CO_2 Capture & Storage

An Overview

Hank Courtright
Senior Vice President

Worldwide CO_2 Storage Potential



Source: IPCC

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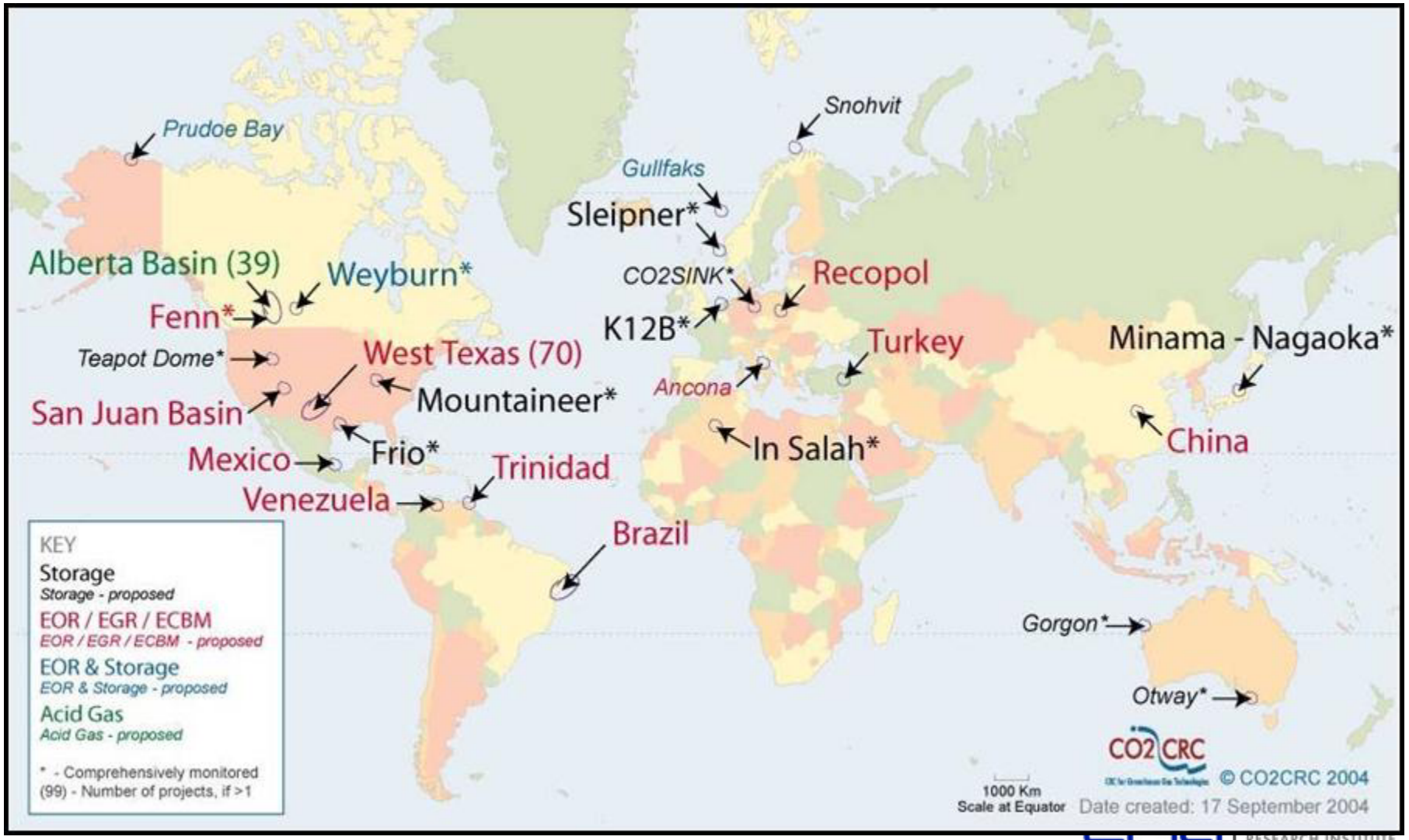
CO_2 Storage Related Activities Underway or Proposed



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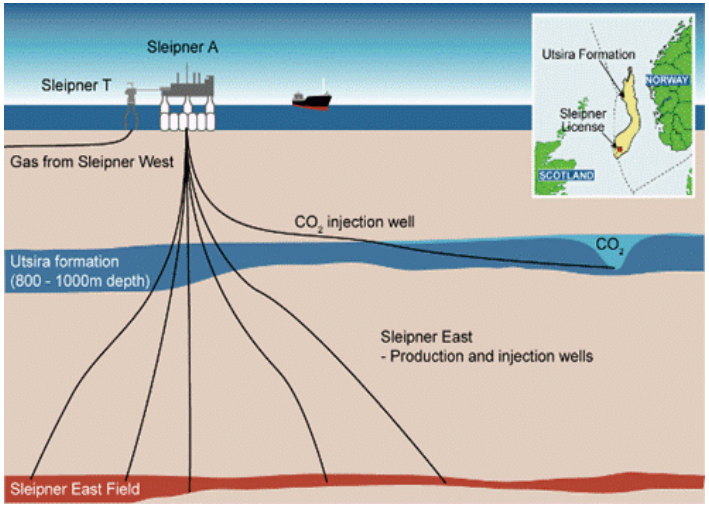
Sleipner Project, North Sea

- 1996 to present
- 1 Mt CO_2 injection/yr
- Seismic monitoring



Picture compliments of *Statoil and LBNL*

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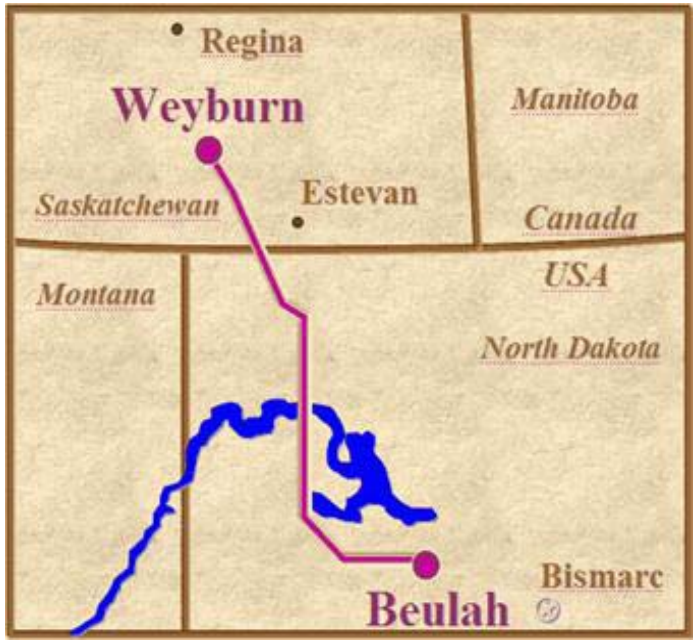
Weyburn CO_2-EOR and Storage Project

- 2000 to present
- 2.7 Mt/year CO_2 injection
- CO_2 from the Dakota Gasification Plant in the U.S.



Photo's and map courtesy of PTRC, Encana, and LBNL

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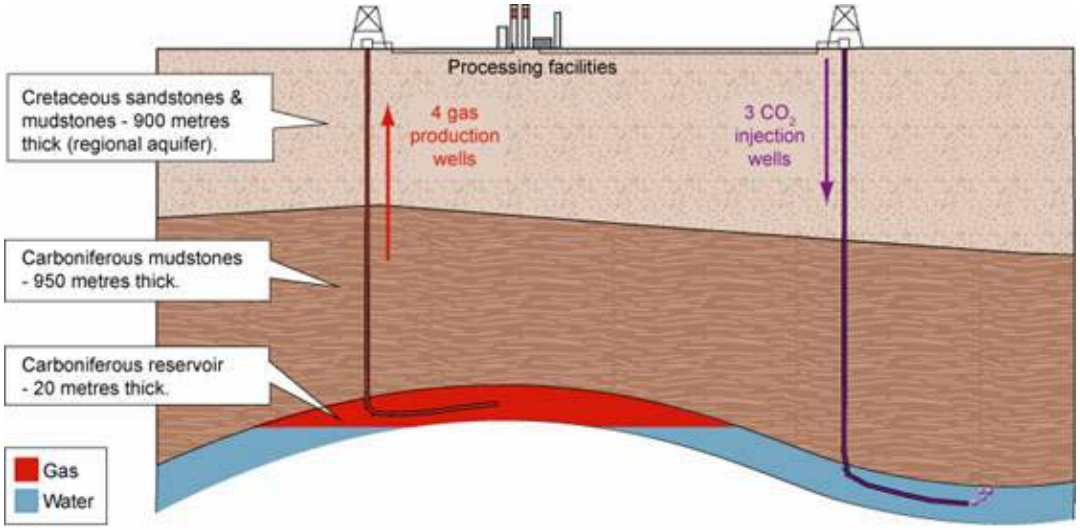
In Salah Gas Project

Salah Gas Project
- Krechba, Algeria

Gas Purification
- Amine Extraction

1 Mt/year CO_2 Injection

Operations Commence
- June, 2004



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Slide courtesy of BP and LBNL

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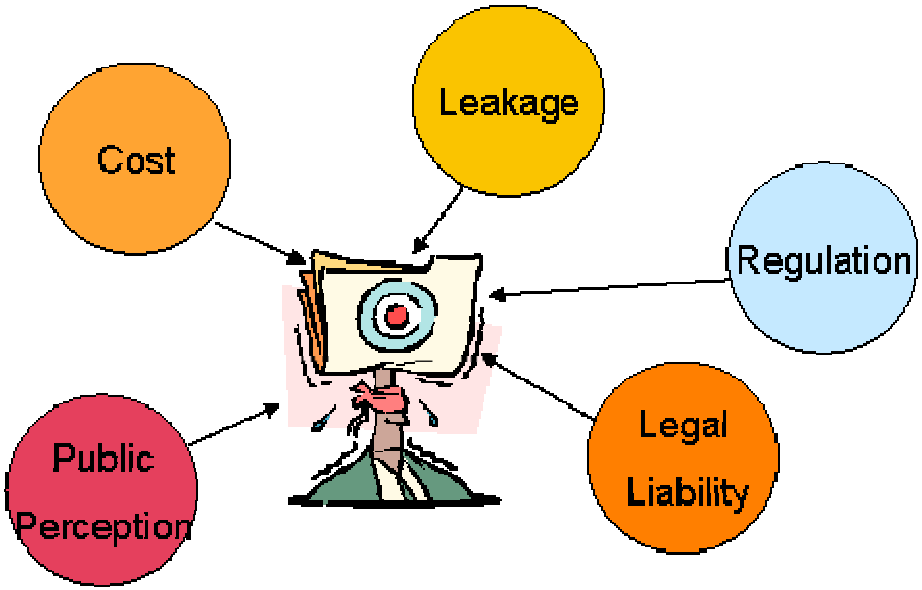
Risk Management

- **Leakage**
- **Environmental Impacts**
- **Permitting**
- **Legal Issues**



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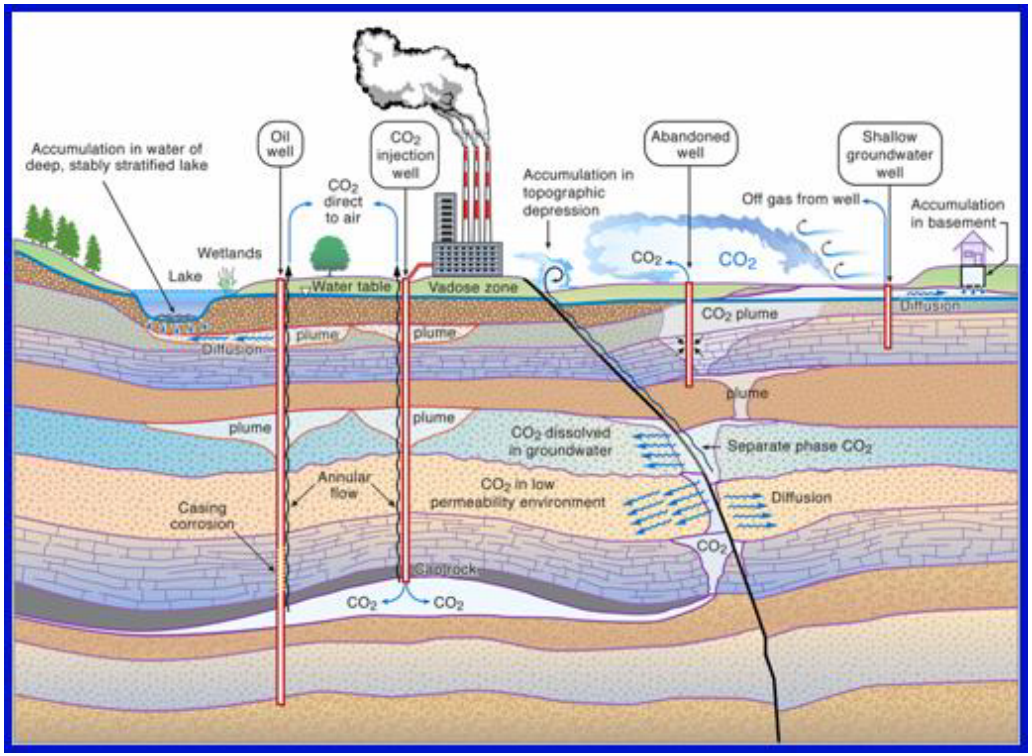
Understanding the Risk
Storage Failure Mechanisms

- Leakage through poor quality or aging injection well completions
- Leakage up abandoned wells
- Leakage due to inadequate caprock characterization
- Inconsistent or inadequate monitoring



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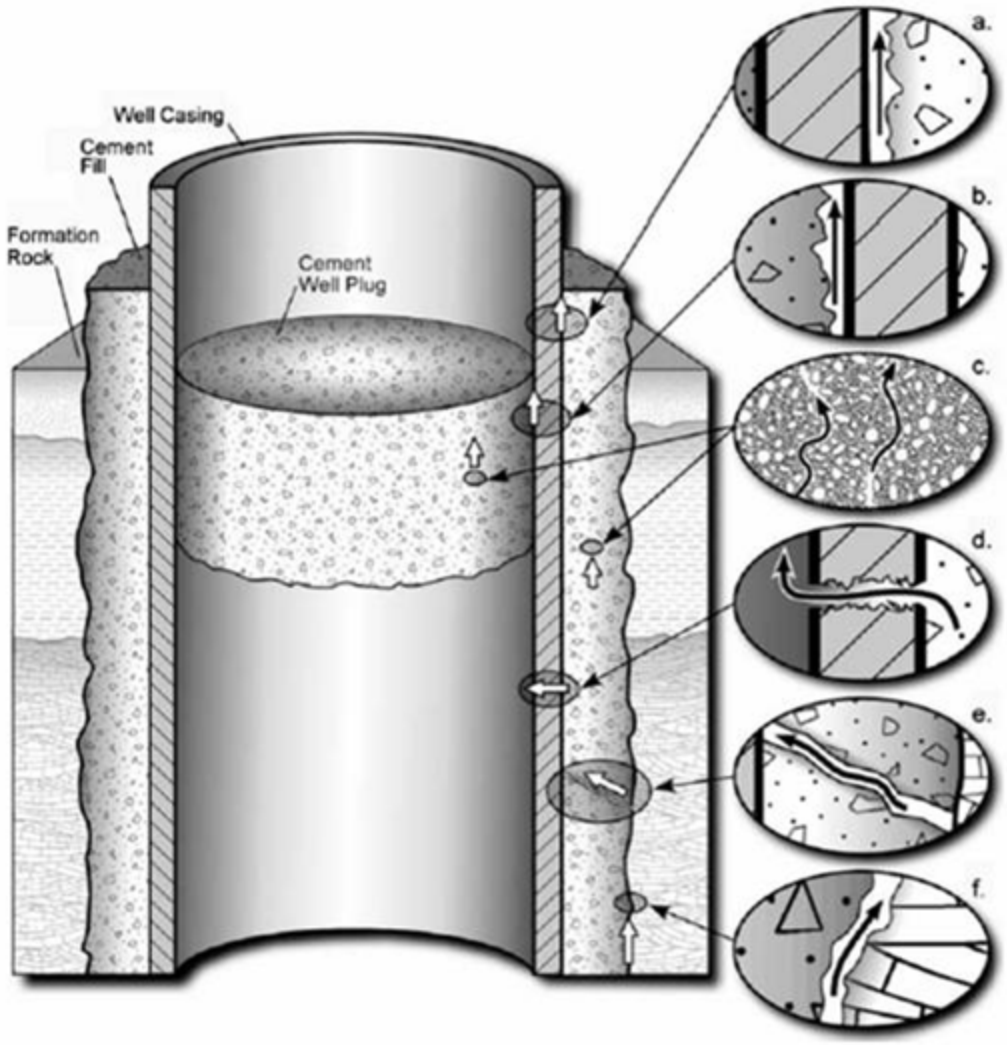
Well Bore Integrity



Scherer et al., 2005

- In lab CO_2 reacts with Portland cement rapidly
- Not experienced in field, but 30 years of service shows some increased corrosion
- Develop a project to evaluate a CO_2 Injection well

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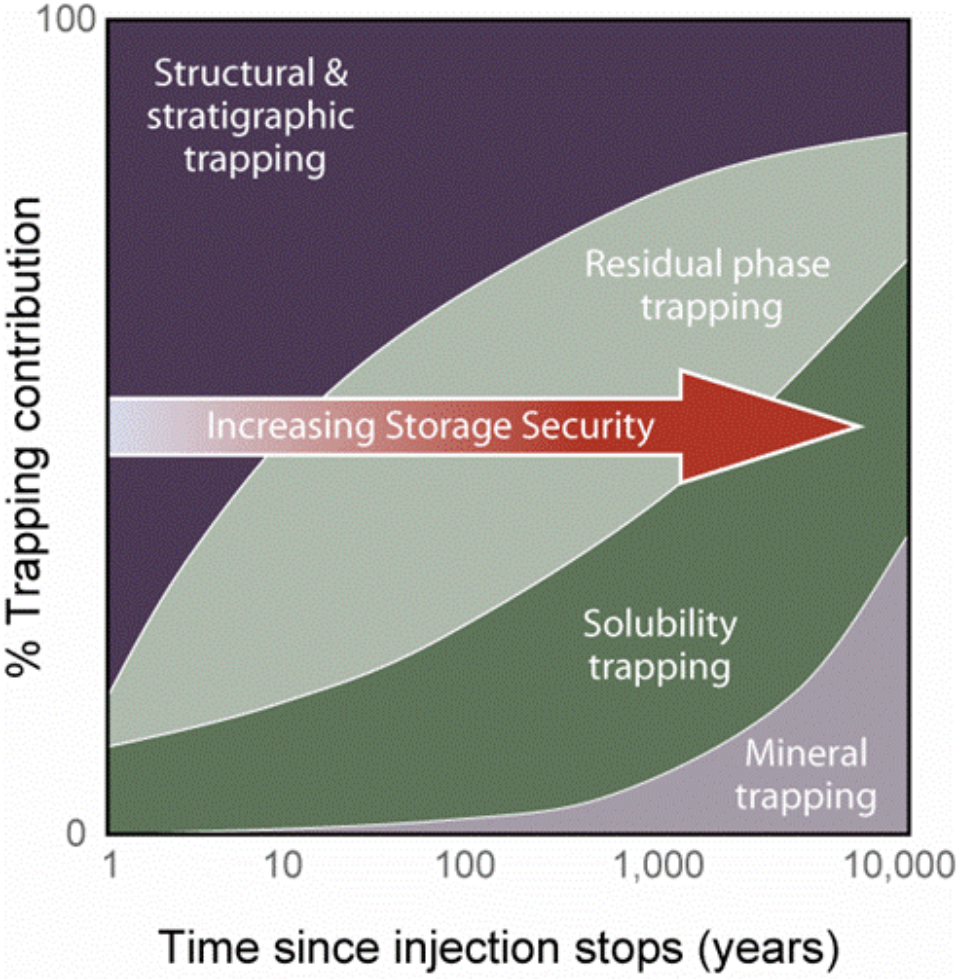
Temporal Evolution of Trapping Mechanisms

Storage security should increase with time at an effective storage site.



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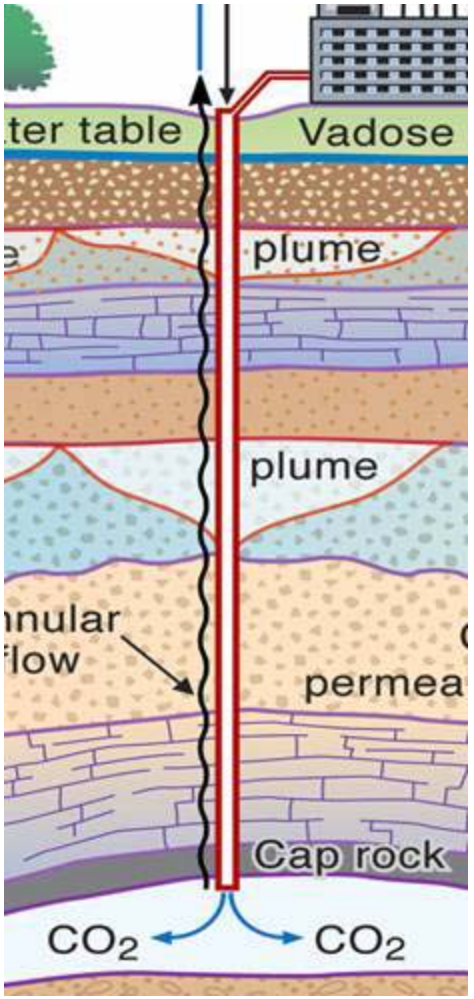
DOE CO2 Sequestration Regional Partnerships - *Phase II*

- 22 Geologic Injection Tests
  - 8 Enhanced Oil Recovery /Saline
  - 6 Saline Reservoirs
  - 8 Enhanced Coal Bed Methane / Enhanced Gas Recovery
  - Test injections are between 1,000-450,000 tons of CO_2



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EPRI CO_2 Capture Initiative

A multi-phase testing program to develop cost-effective and practical PC CO_2 capture technologies

Phase 1

- **5 MW Chilled Ammonia Pilot with Alstom**
- **Testing of other solvents or technologies**
- **Test materials to be used for compression, transport and injection of flue-gas CO_2**

Phase 2

- **Larger CO_2 Test Center (possibly up to 100 MW)**
- **Capture and store CO_2 at substantial scale and real operating environments**
- **Future phases – larger demos to scale-up to full plant**

Focused on closing the PC CO_2 capture cost gap

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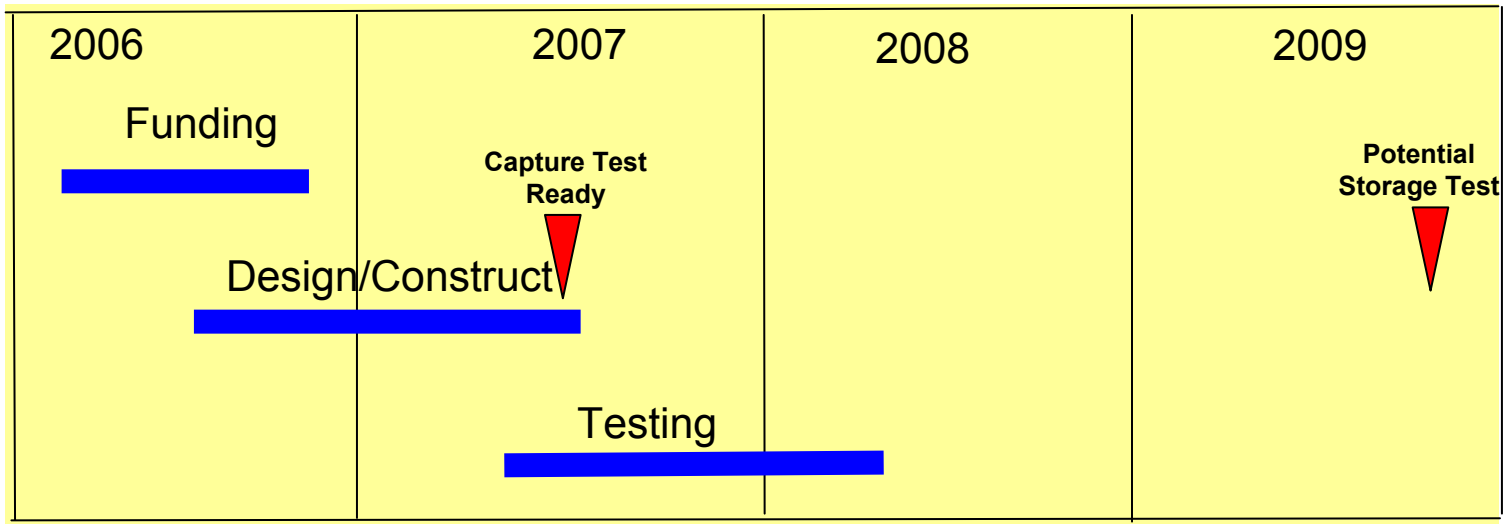
Phase 1 5MW Project Schedule



Targeting Test Results in 2008

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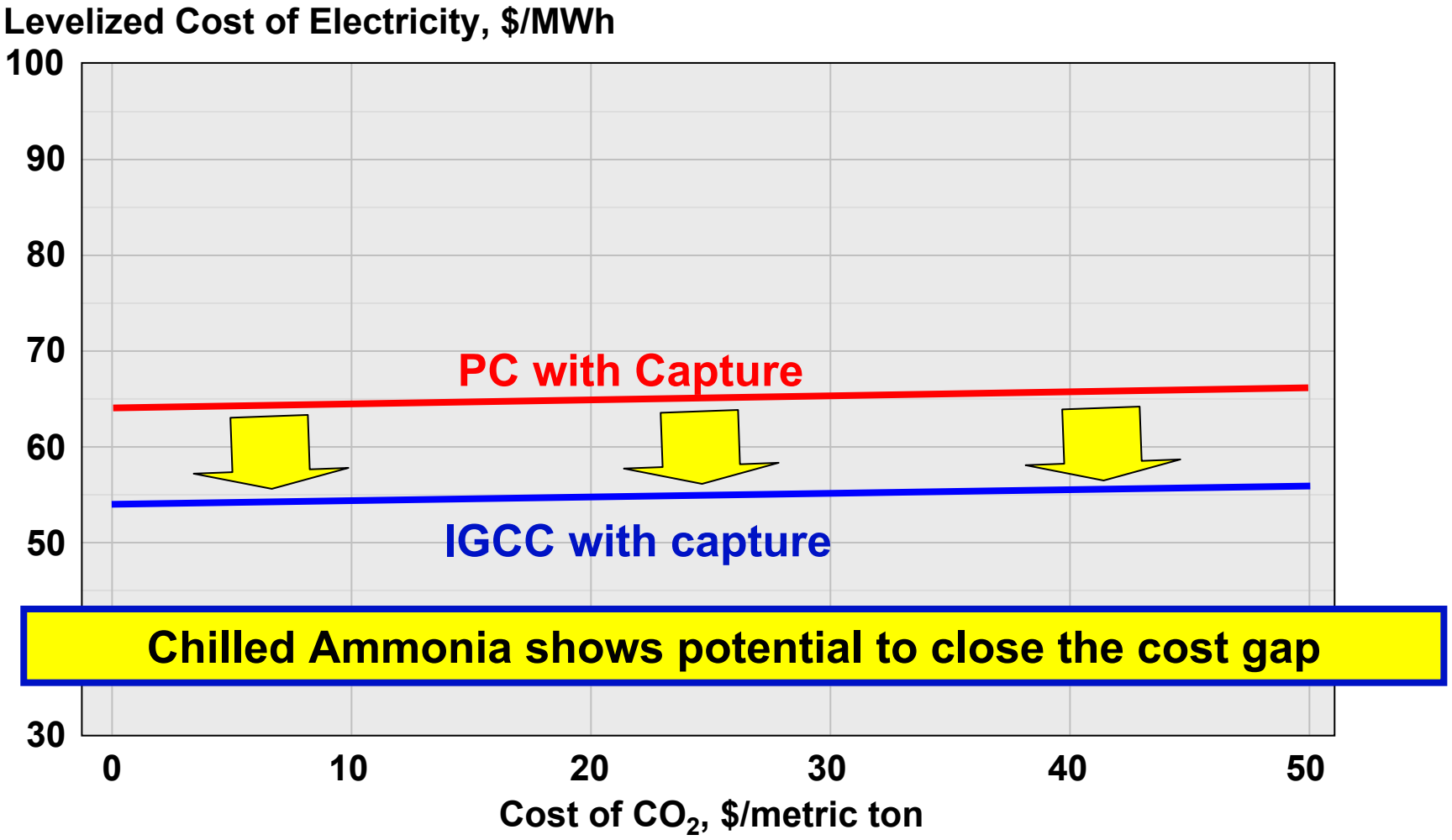
Closing the Capture Cost Gap



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Transport Issues

- The technology is relatively straightforward but there are some questions
  - What impurities are allowable?
  - Must it meet current commercial pipeline specifications?
  - What will permitting be like if the pipeline is not in rural areas?

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Public Awareness

- Surveys in Europe and North America indicate public awareness of CO2 Storage is limited
  - But, awareness of impacts of climate change is extensive
- After explanation of technology the public surveyed were not against technology
- Need to build public awareness of need for and benefits of CO2 Storage
- Public need to be engaged early in an open and transparent process

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ADDITIONAL REFERENCE SLIDES IF NEEDED FOR DISCUSSION SESSION

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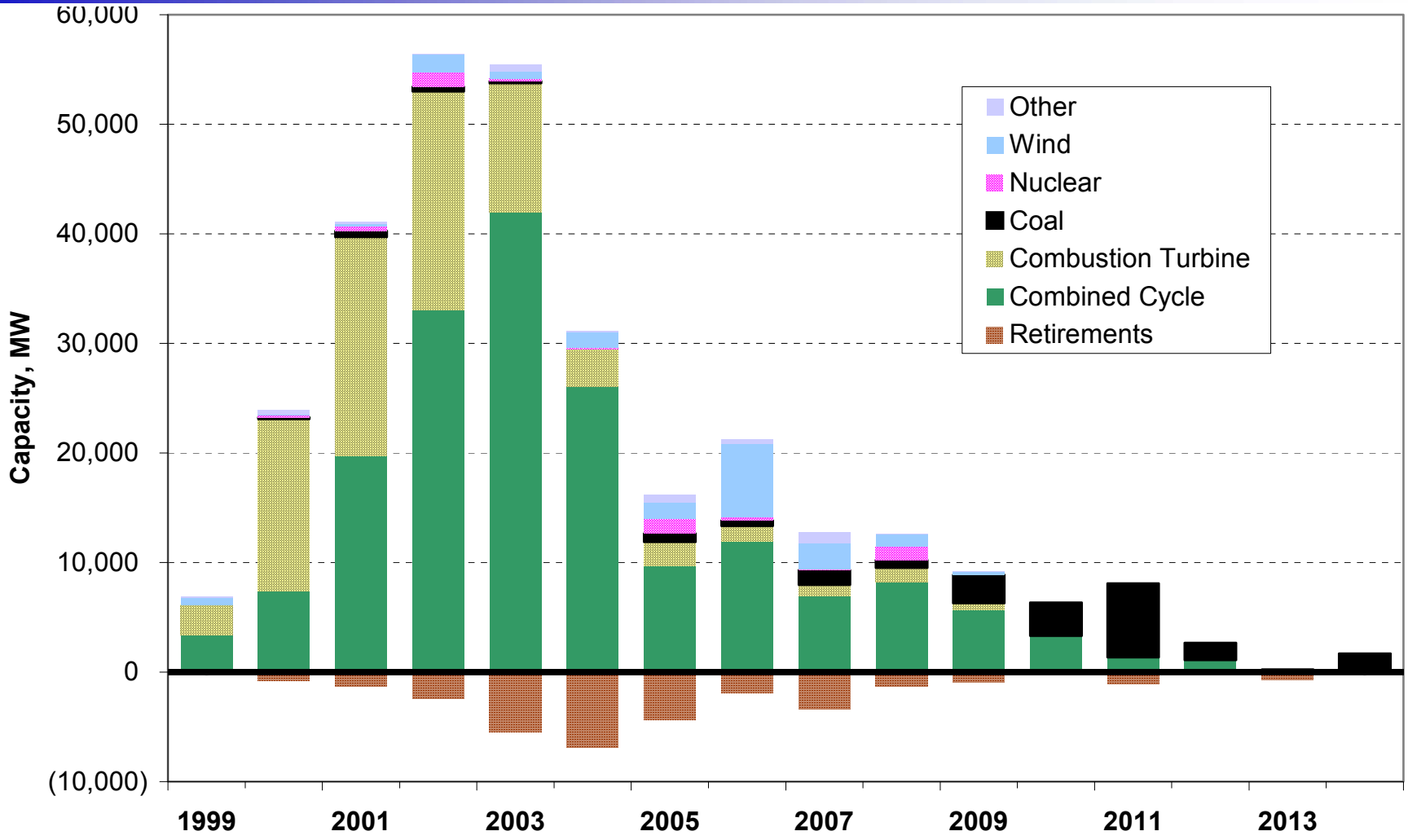
U.S. Capacity Additions 1999-2014



Ref.: EPRI P67 Newsletter on New Power Plants, September 2005

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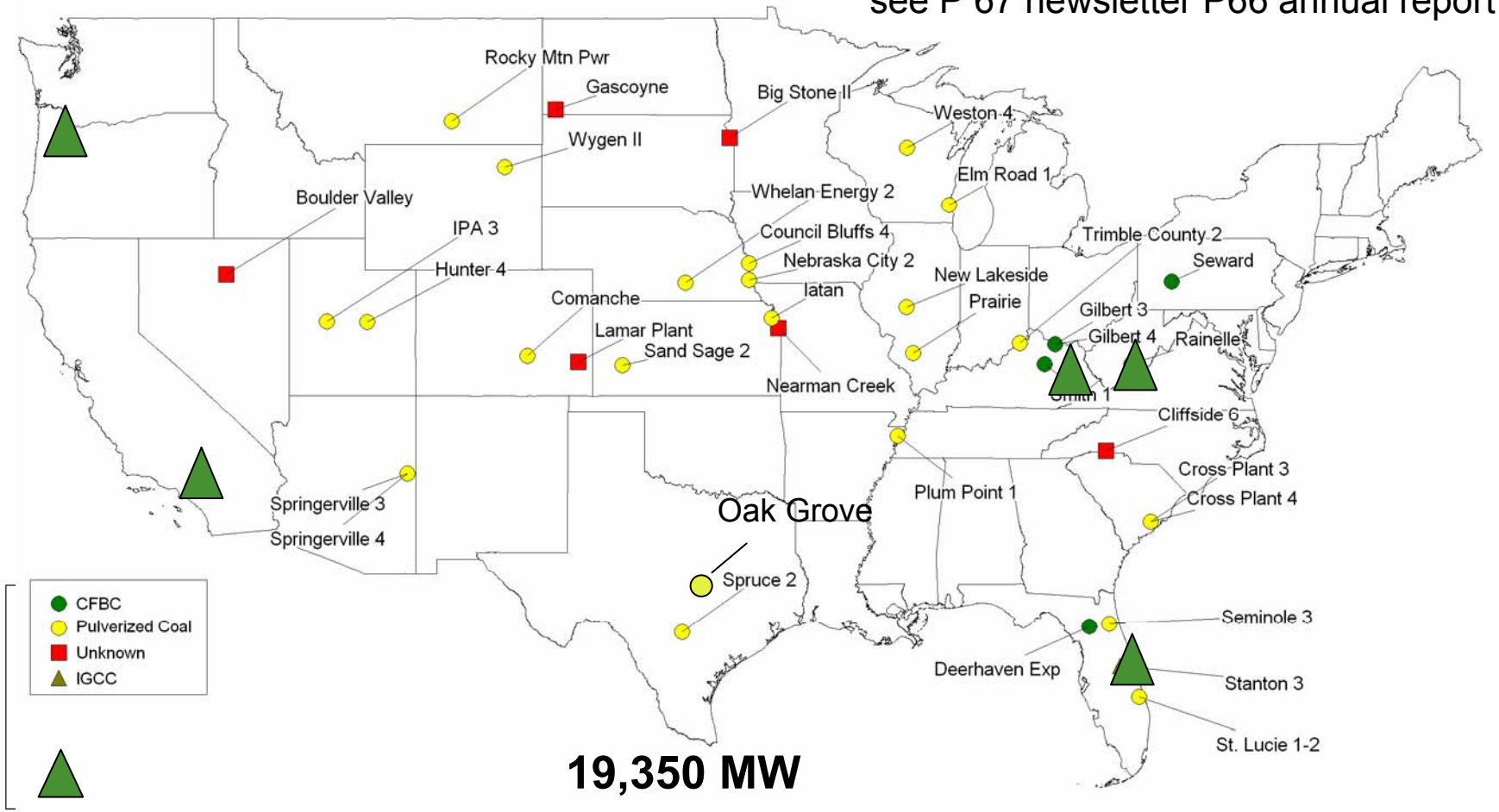
Coal Plants 2005-2014

Coal is Under Development

Newest IGCC proposed sites Added to graphic – see P 67 newsletter P66 annual report



Source: EPRI Program 67 Newsletter: *Energy Markets and Generation Response – Update on New Power Plants*, September 2005.

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IGCC Status, Markets and Vendors

- 4 Single train coal-based IGCC 250-300 MW on coal/coke operating
- Main needs are capital cost reduction and availability improvement. Federal Energy Act of 2005 (EPACT 2005) contains incentives.
- AEP, and Duke (previously Cinergy) plan ~600 MW coal plants. Several others in development including co-production (ammonia, synthetic natural gas, liquids).
- Technology needs improvement in economics for low-rank coals (e.g.., Powder River Basin).
- Petroleum Residuals (8 worldwide) - Energy Northwest and BP& EMG plan ~ 600-500 MW coke fueled (BP & EMG make hydrogen).
- Vendor teams (for coal and pet coke) GE/Bechtel, ConocoPhillips/Fluor/Siemens, Shell/Uhde/Black & Veatch, New Siemens acquisition of German Future Energy – Announced May 2006

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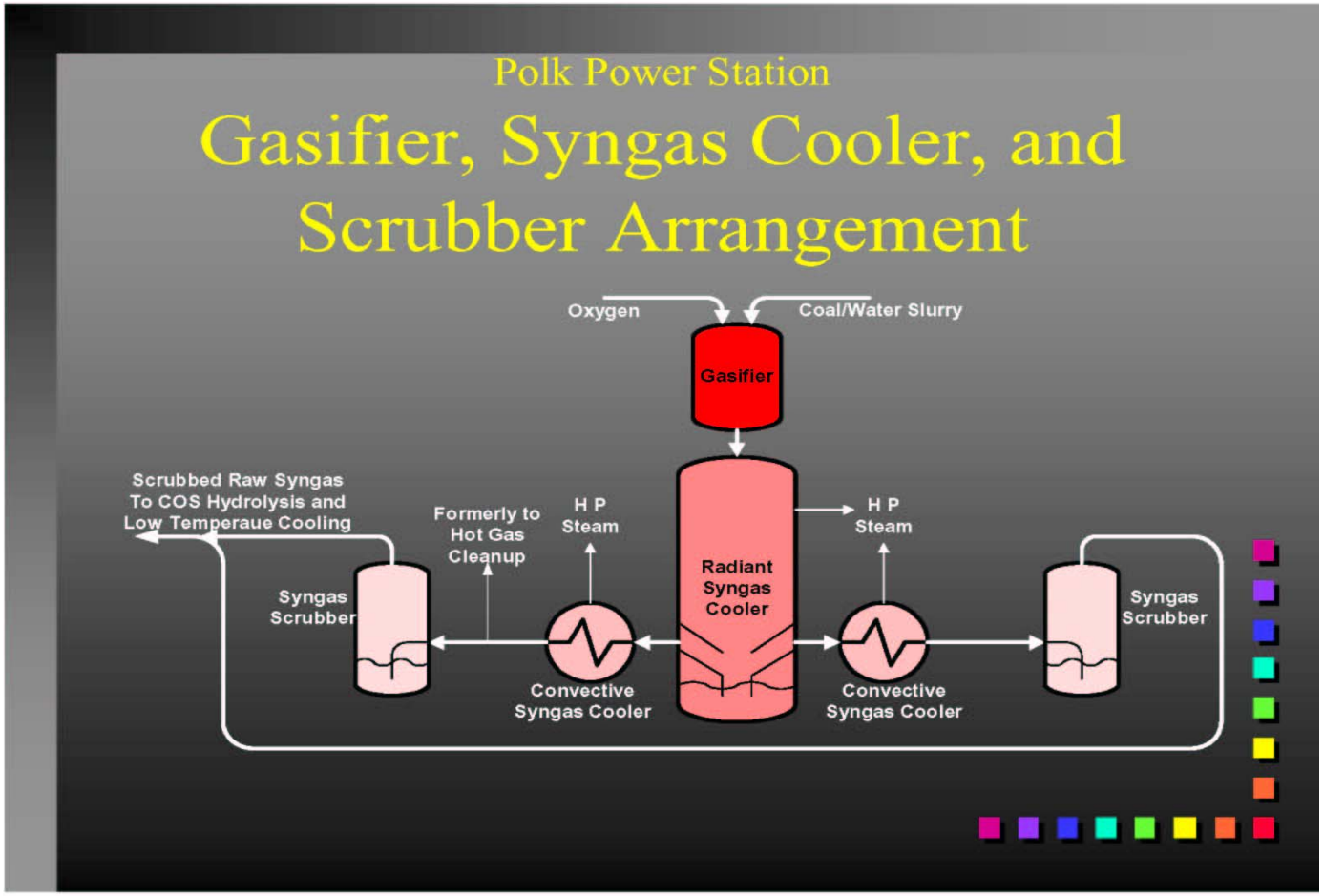
Polk Gasification Arrangement (Texaco – now GE)



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Polk Gasifier Texaco (now GE)

- Water slurry fed design
- Issues on Powder River Basin Coal –
  - •Reduced efficiency with PRB.
  - •GE working on improved performance with PRB.
  - •Can blend PRB with Pet. Coke if available.

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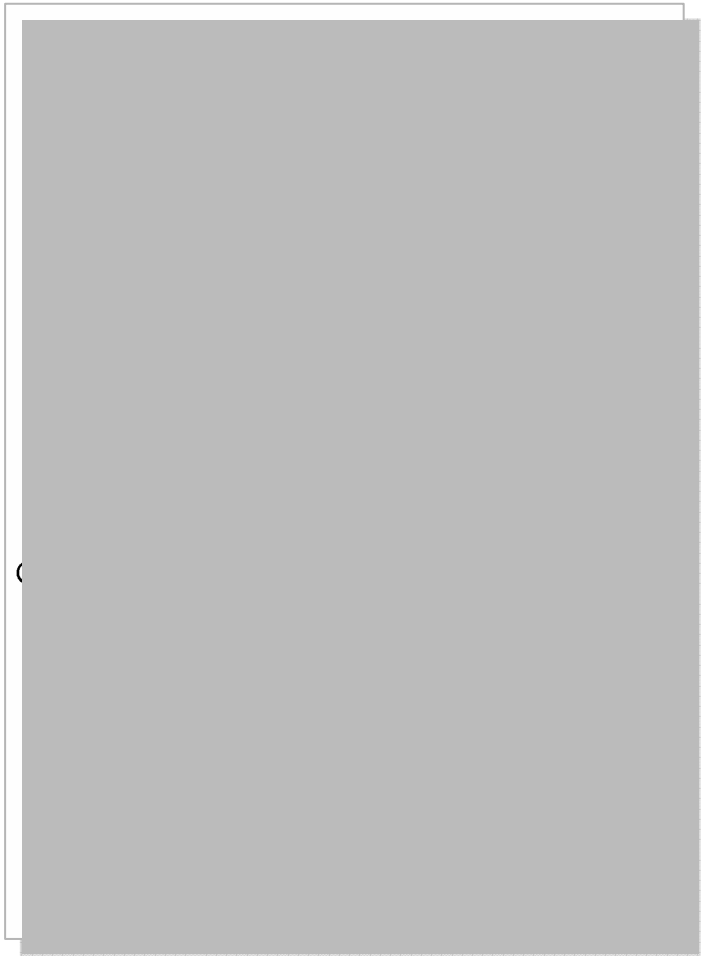
E-Gas Gasifier—As Used at Wabash River (Technology Now Owned by ConocoPhillips)

- Water slurry fed
- PRB Issues
  - •Reduced efficiency with PRB.
  - •Latest High Pressure design offers some improvement for PRB.
  - •Can blend with Pet. Coke if available (as planned at Excelsior and ENW)
- Multi-stage design in development



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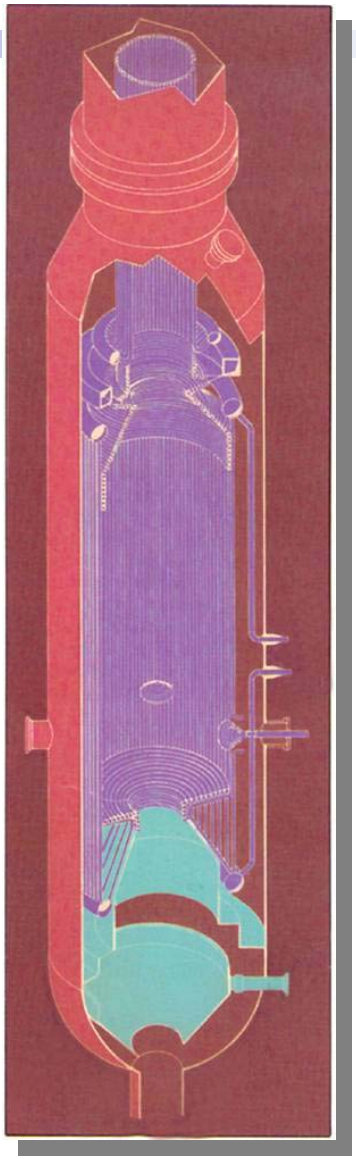
Shell Gasifier Cutaway

- Uses Dry Feed (better on Powder River Basin Coal)
- Water walls (less maintenance and outage than with refractory)
- Current offering has high Syngas Cooler (SGC) cost.
- Lower cost partial quench design being developed



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