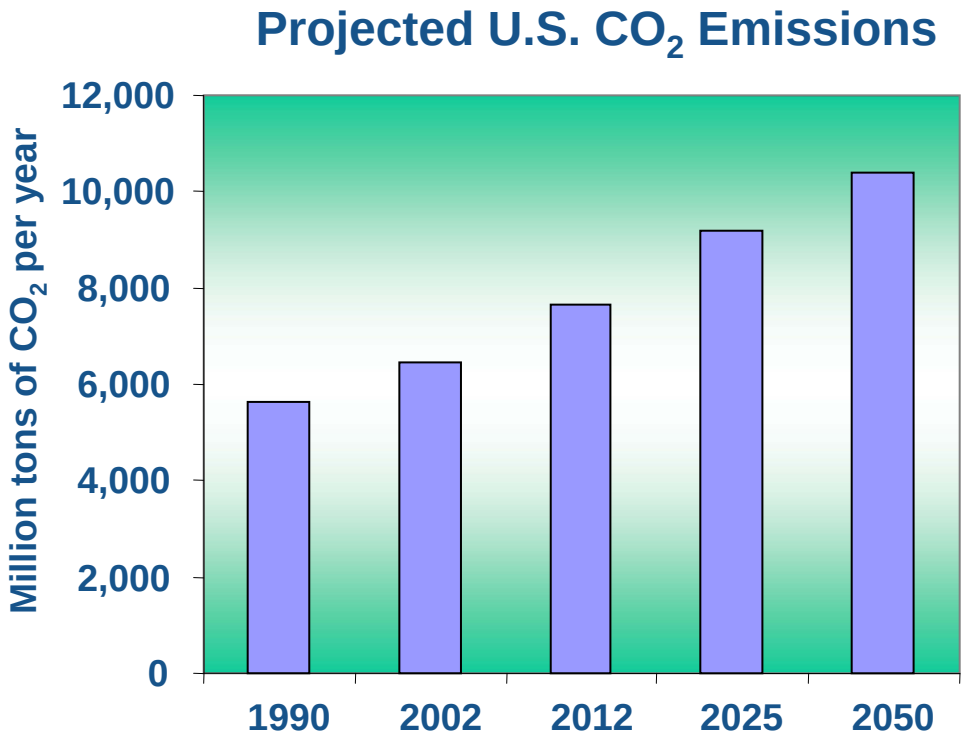
U.S. Near-Zero Emissions Program: CCS - Clean Coal R&D, FutureGen, & Demonstrations

Office of Fossil Energy
CSLF Capacity Building Workshop
Mexico City, July 2008

Growing Population and Economy Mean Continued Increases in CO_2 Emissions



Reference case assumes advanced technology but no mandatory CO_2 limits

Data Sources: 1990 - 2025, U.S. DOE Energy Information Administration., historical data and reference case forecast from the AEO 2004. 2050 projection from NETL Carbon Sequestration Program benefits analysis, based on 1.7% annual growth rate of GDP post 2025 and 1.63% reduction in carbon emissions per GDP

Why Sequestration?

- May be only option that removes enough carbon to stabilize CO_2 concentrations in the atmosphere
- Only approach that doesn't require countries to overhaul energy infrastructures
- May prove to be a low-cost carbon management option

Carbon Management Paths

- Switch to low- and no-carbon fuels
  Renewables, Nuclear, Natural Gas
- Increase energy efficiency
  Demand-Side & Supply-Side
- Sequester carbon

- Capture and storage is capable of providing up to 55 percent of the emissions mitigation needed to achieve stabilization and at less cost than other alternatives

Carbon capture and storage (sequestration) needs to be proven safe and feasible at large scale. DOE is working with partners to demonstrate this technology.

Technical Challenges to CCS

- **Technology is available today for carbon capture from new and retrofitted coal-fired IGCC and PC power plants, however:**
  - **It is very expensive**
  - **Parasitic load is very high**
  - **Reliability needs to be proven**

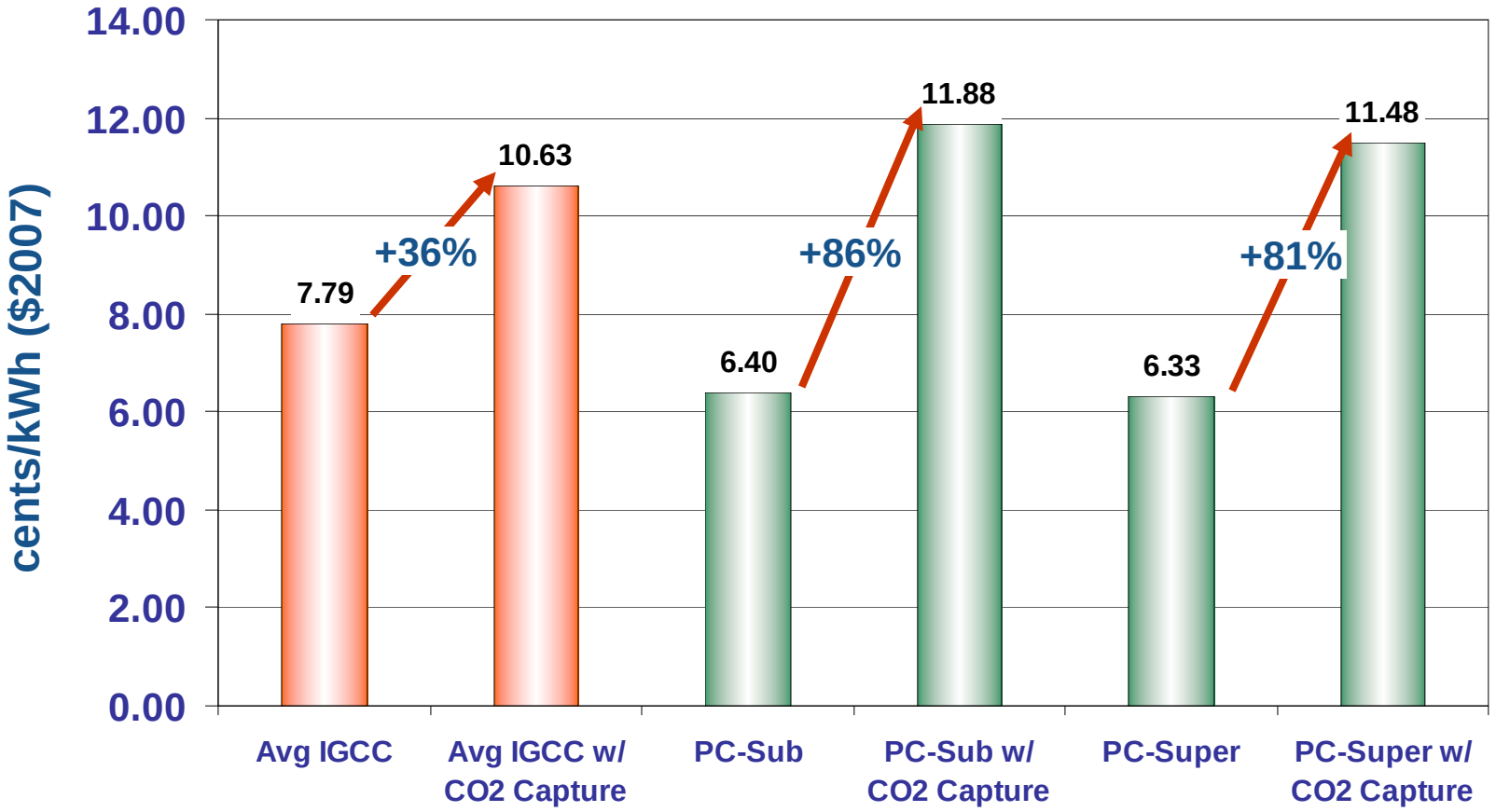
- **Sequestration needs to be adequately demonstrated, especially in deep saline reservoirs with large-volume CO_2 injection**

Carbon Capture and Storage (CCS)

- **Three elements of CCS:**
  - ***Capture*** **– accounts for over 90% of the CCS cost due to high capital cost and energy penalties**
  - ***Transport*****- requires infrastructure, pipeline, right of ways, limited by economics of transport distance.**
  - ***Storage*****- safety, long-term storage, liability, land and mineral access rights for geologic storage.**
- **Research focuses on cost and energy penalty reductions and providing a scientific and operational basis for safe and effective injection and long-term storage**

Cost of Electricity Comparison -- New Plants

(Baseline Study – Bituminous Coal)



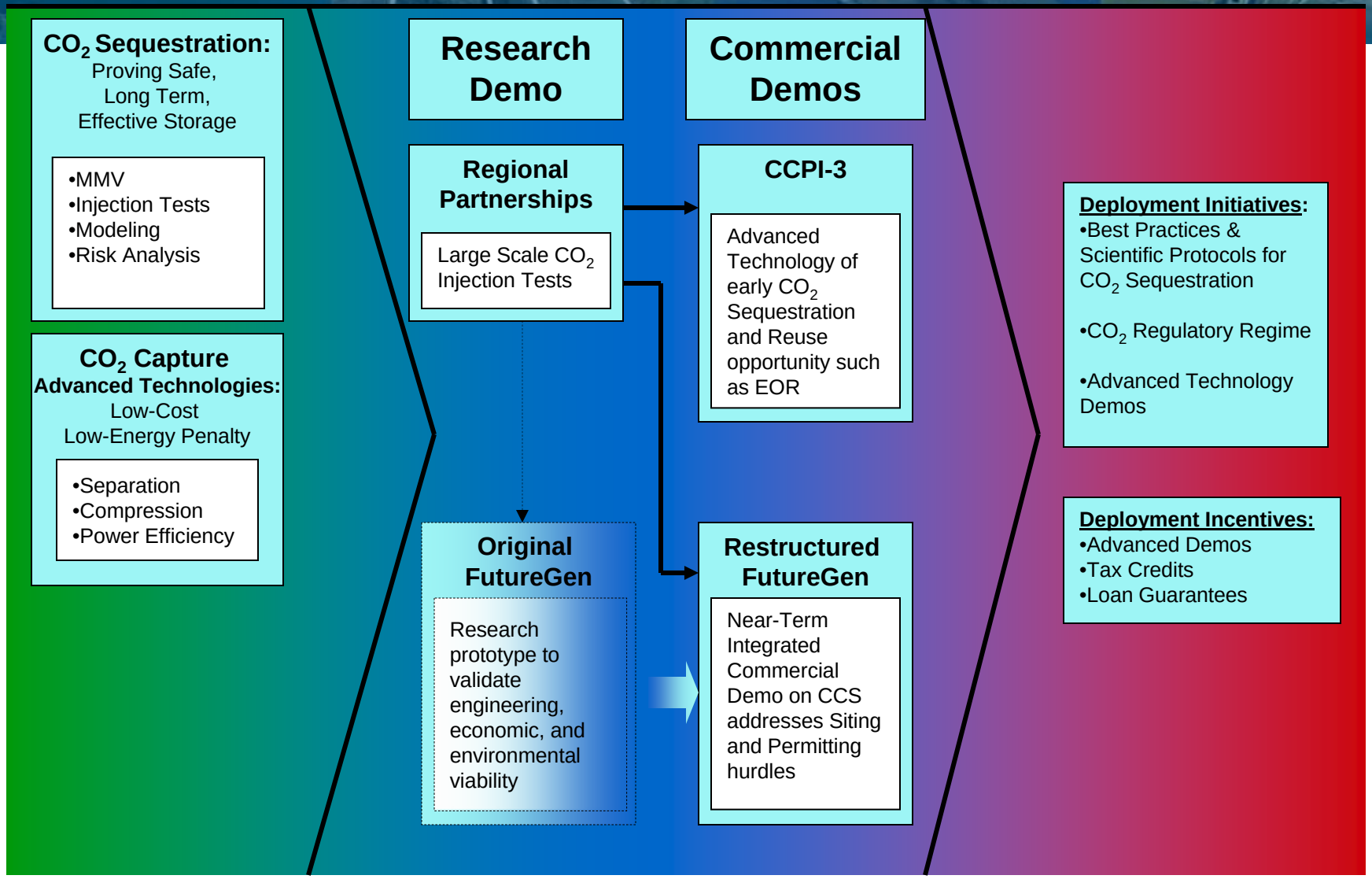
January 2007 Dollars, Coal cost $1.80/$10^6$ Btu

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

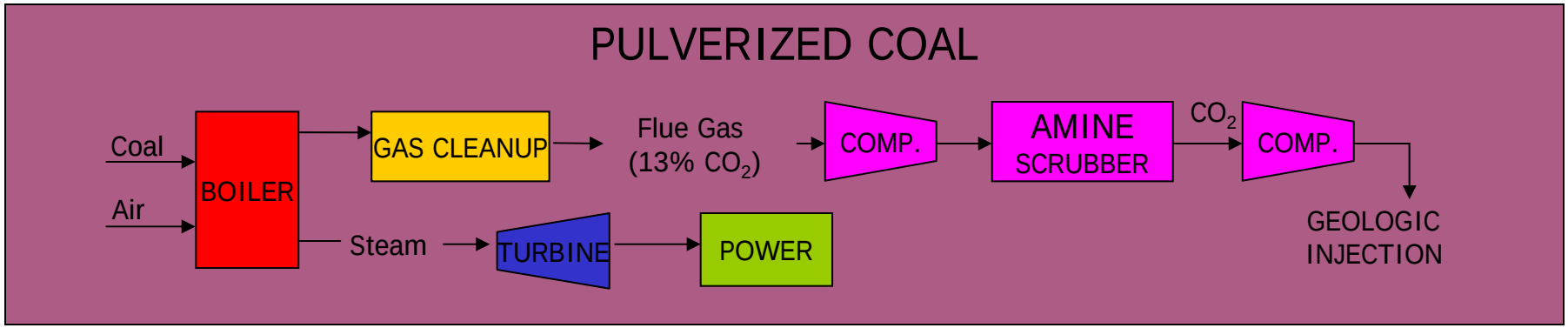
A Perspective on U.S. Activities on Clean Coal

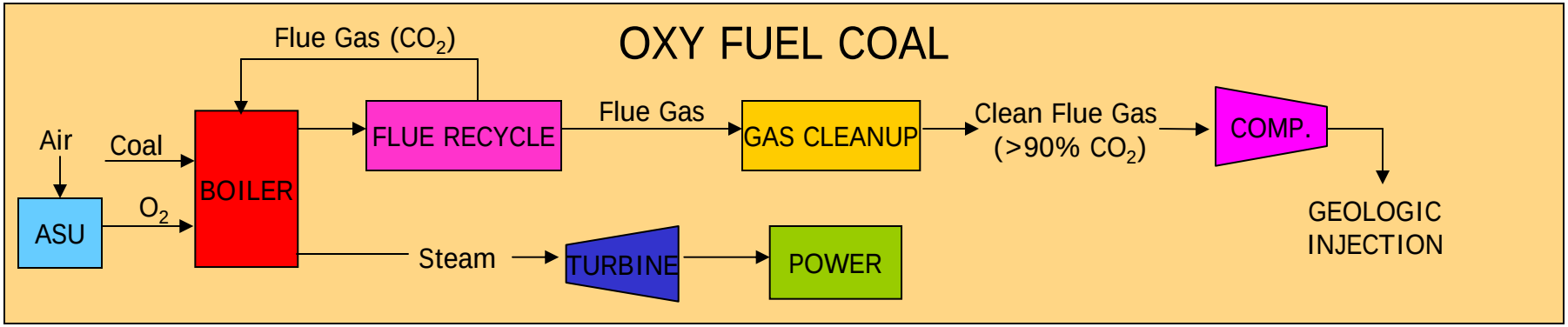
- DOE budgets include: funding for research, development, and demonstration of advanced technologies;
- Over the past 5 years DOE-FE funded research on CCS and Clean Coal was approximately $3.5 billion.
- EPAct 2005 authorized $1.65 billion in tax credits for clean coal projects with priority given to green house gas capture capability.
- DOE FY-08 the appropriations include $8 billion for loan guarantees, $6 billion of which require carbon capture or beneficial reuse of CO_2.
- Significant increases in private sector investments have been realized
- Still hurdles to overcome in advancing Clean Coal technology:
  - Public perceptions to new coal plants can produce local resistance (NIMBY)
  - Escalations in labor and material costs
  - Technical, regulatory and financial challenges remain in getting technology deployed
- Our Near Zero Emission Coal program, including Restructured FutureGen is aimed at providing affordable CCS technologies for broad, effective, global deployment.

Near Zero Emissions Coal

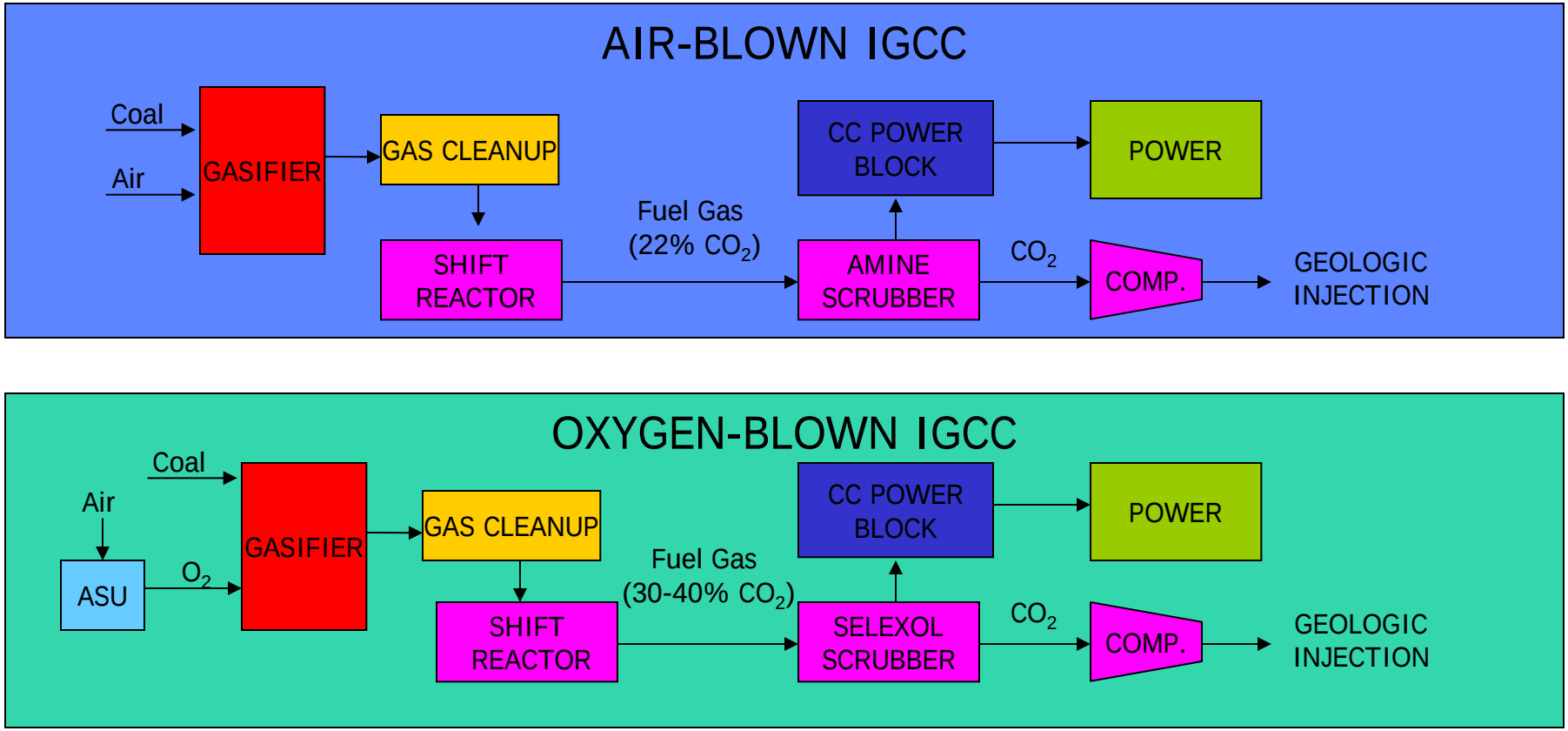


Combustion Coal Plants With Sequestration





IGCC Coal Plants With Sequestration



Innovations for Existing Plants (IEP)

IEP Program redirected its focus to include advanced CO_2 capture technology for existing coal combustion- based plants, e.g. conventional pulverized coal-fired plants.

- **Applying current technologies to existing power plants with an average efficiency of 33% would reduce net power plant output by approximately one-third.**
- **The focus on CO_2 emissions control technology is both post-combustion and oxy-combustion and related areas of CO_2 compression and CO_2 beneficial reuse.**
- **The program goal is to develop advanced CO_2 capture and separation technologies for existing power plants that can achieve at least 90% CO_2 removal at no more than a 35% increase in cost of energy services.**

R&D to Reduce Cost of CO_2 Back End CCS For PC Plants

Cost Item	COE Increase w/CO_2 Capture (mills/kWh)	Cost Reduction Potential (%)	COE Increase w/CO_2 Capture (mills/kWh)*	Examples of Research Areas/Benefits
CO_2 Capture Capital	14	50	7	Advanced sorbents/solvents w/ increased capacity and reaction kinetics decrease equipment size; advanced membranes and oxy-combustion obviate need for solvent/sorbent regeneration equipment; chemical looping eliminates cryogenic O_2 equipment; advanced compression reducing size/stages of compression
Fixed Operating	1.4	20	1.1	Reducing size and complexity of capture equipment reduces manpower needed to operate equipment
Variable Operating	3.4	80	0.7	Improving stability, adsorption capacity and rate, resistance to contaminates/degradation/attrition, etc. decreases amount of solvent/sorbent needed; advanced membranes and oxy-combustion eliminate/reduce/eliminate need for sorbent/solvents; chemical looping reduces cost of O_2
Energy Cost	33	65	11.6	Advanced solvents/sorbents with lower heat of reaction decrease thermal regeneration requirements; membranes/oxy-combustion/chemical looping eliminate need for thermal regeneration; integration of heat recovered from advanced compression technology
CO_2 transport, Storage, & Monitoring	3	20	2.3	Improvements in CO_2 transport, storage and monitoring being carried out under Carbon Sequestration Program
Total	~55		~23	
COE Increase (%)	~85		~35%	

*Assuming success in achieving research goals.

RD&D for IGCC and CCS

Research Area	Research Technologies	Cost of Electricity	Net Power Output
Gasifier Island	-O_2 Membranes -Advanced Transport Reactor - Raw Gas Shift Reactor	6-15% Reduction	4-11% Increase
Power Island	-Low NO_x Hydrogen Turbines -SECA Fuel Cells ($400/kW)	7-25% Reduction	10-20% Increase
CCS	-H_2 Membranes -Advanced Selexol -Novel Chemistry	Can Reduce COE Penalty from 60-80% for Amine to less than 10%	Can Reduce Energy Penalty from 30% for Amine to 5% range

Clean Coal Power Initiative (CCPI)-3

- Draft CCPI-3 solicitation has been issued and comments received. Anticipate issuing final solicitation before end of FY2008.
- Focus of CCPI-3 is demonstration of advancements in technology from R&D program combined with carbon capture.
- Opportunities for CCS Retrofit Demonstrations to Existing Plants
- Allows for near-term opportunities for beneficial re-use of CO_2 (e.g., Enhanced Oil Recovery)
- Open to advancements in combustion systems as well as IGCC.
- Demonstration projects are minimum 50 percent cost-share from industry.

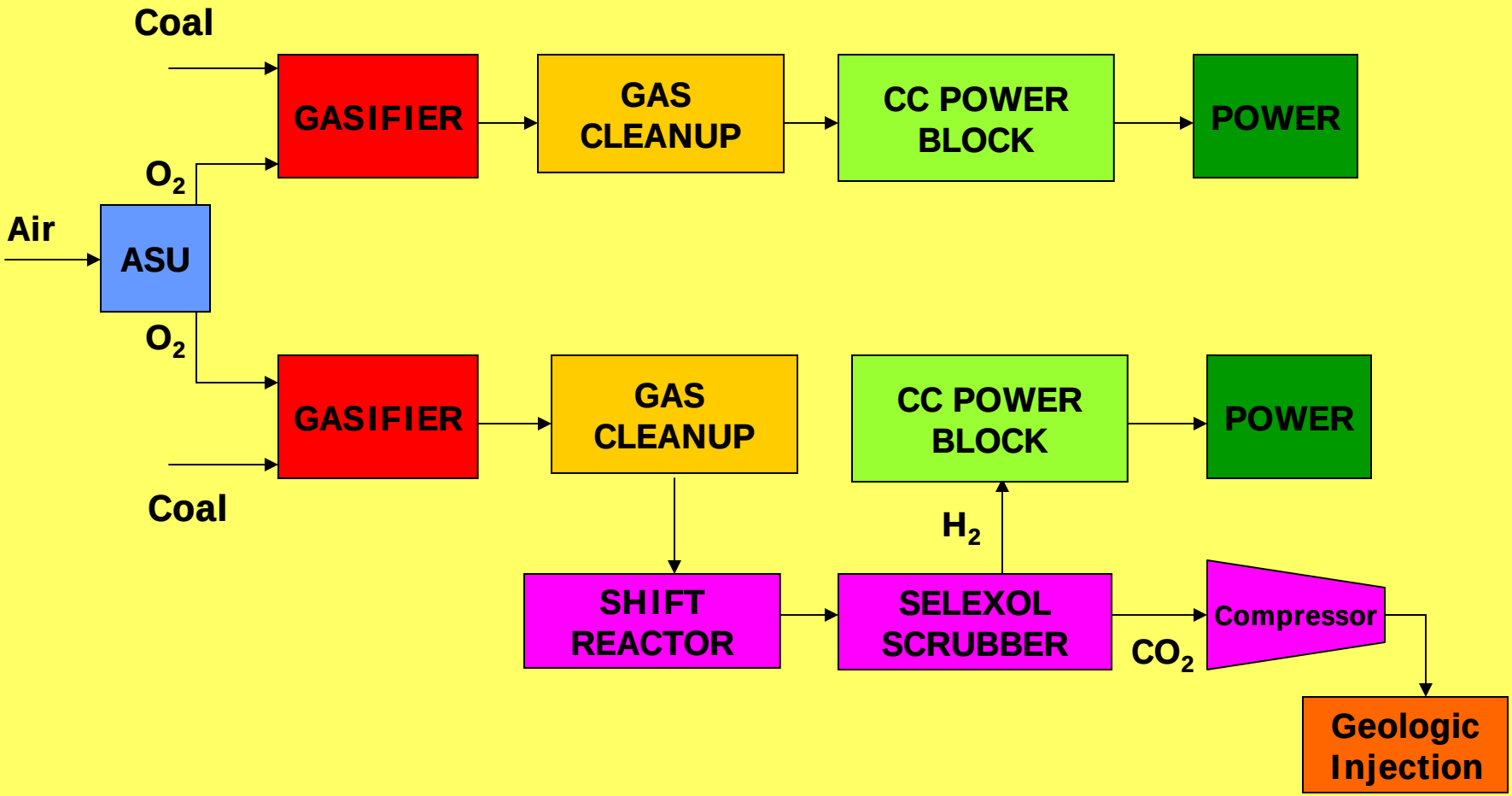
Restructured FutureGen's Strategic Approach

- A focus on early deployment of CCS for near-zero emission coal (IGCC and advanced coal systems with CCS) through multiple commercial demonstrations.
- Address the feasibility and acceptability of CCS by stakeholders and public (i.e., can near-zero emissions plants be sited, permitted, financed, operated reliably, and can the regulatory framework for CO_2 storage be established regionally).
- Address early on the challenges of near-zero emissions plants, including siting and permitting issues, and help drive the regulatory frameworks for CO_2 associated with power generation
- Still focuses on the very critical technical feasibility question of near-zero emission coal plants, i.e., integrated operations, nominally 90% capture; and ultra-low criteria pollutants.

Restructured FutureGen Implementation

- Request for Information on Restructured FutureGen issued in January 2008 with comments back in March.
- Evaluating comments to consider in an upcoming Draft Solicitation released May 7.
- Comments received on May 21 on Draft Solicitation.
- DOE issued solicitation for Restructured FutureGen on June 24.
- Proposal responses due October 8.
- Evaluation leading to selections before end of Administration.

FutureGen Restructured



Restructured FutureGen
Engaging the International Community

- **International engagement in the FutureGen concept and CCS remains an important component to gaining broad global acceptance of near-zero emissions coal as a viable means of providing energy security and addressing climate change**

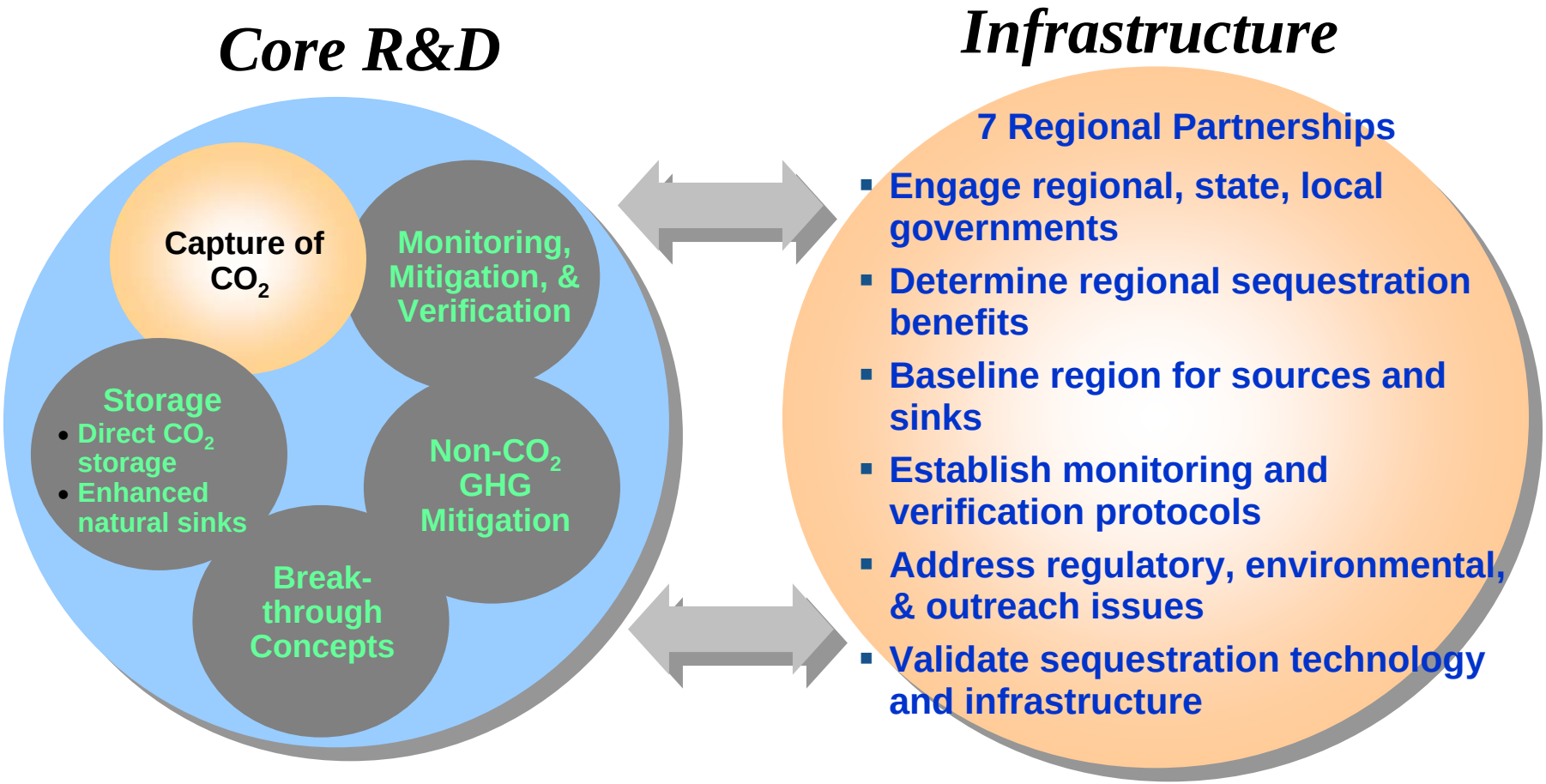
- **DOE is exploring ways to engage governments in deploying Near-Zero Emission Coal plants with CCS for deployment around the world, including FutureGen.**

- **There are currently no restrictions placed on participation from international companies in the restructured FutureGen. Foreign companies can bid on the solicitation when the Final FOA is released.**

FutureGen Restructured
Engaging the International Community

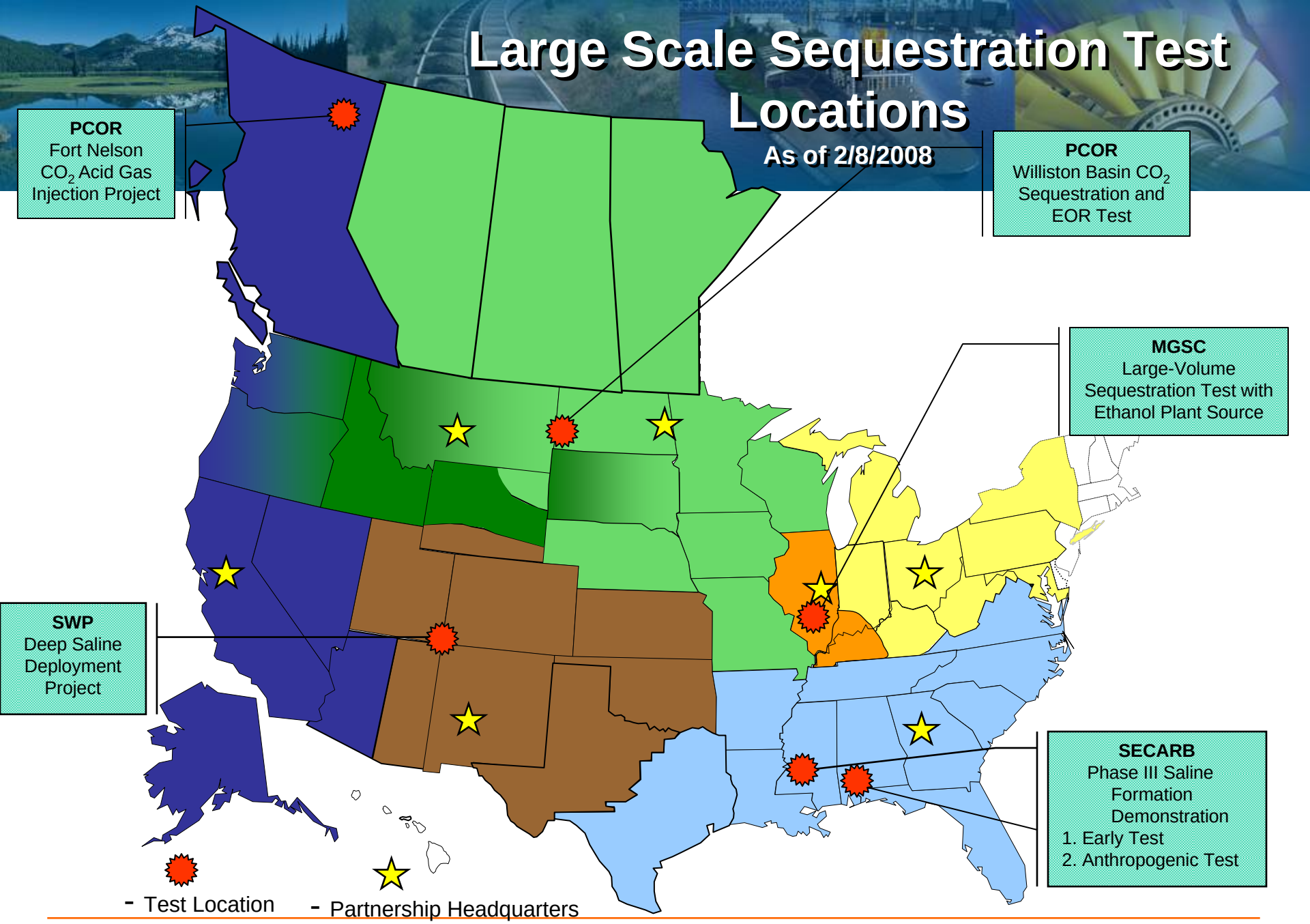
- **Need exists for information exchange (non-proprietary) and cooperation among participating countries on plants with CCS through proven mechanisms such as:**
  - **Government sponsored workshops on: advanced designs and analyses of plant concepts and barriers and solutions encountered by power plant projects with CCS around the world.**
  - **Sponsored symposia comparing status and design philosophies based on non-proprietary information of planned and ongoing large-scale plants with CCS.**
  - **Developing global outreach strategies for acceptance of near-zero emissions coal and CCS to accelerate early global deployment of these technologies.**

DOE's Sequestration Program Structure



Large Scale Sequestration Test Locations

As of 2/8/2008

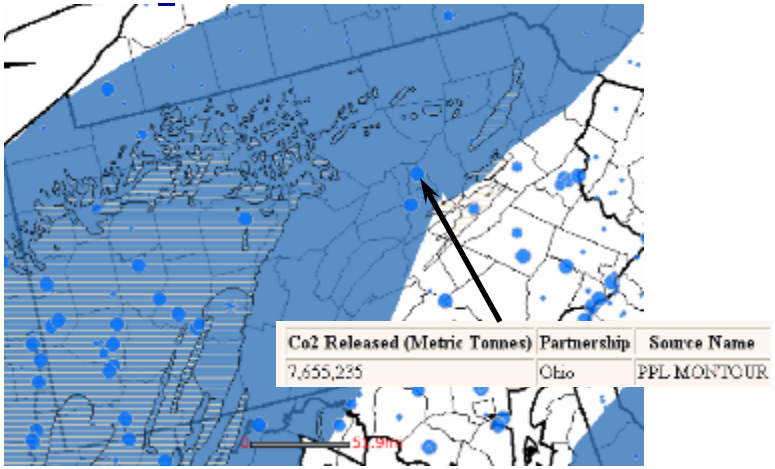


NatCarb's Sequestration Atlas

CO_2 Sinks- Geologic Formations

CO_2 Sources- Electric Generation

CO_2 Source/Sink Overlay



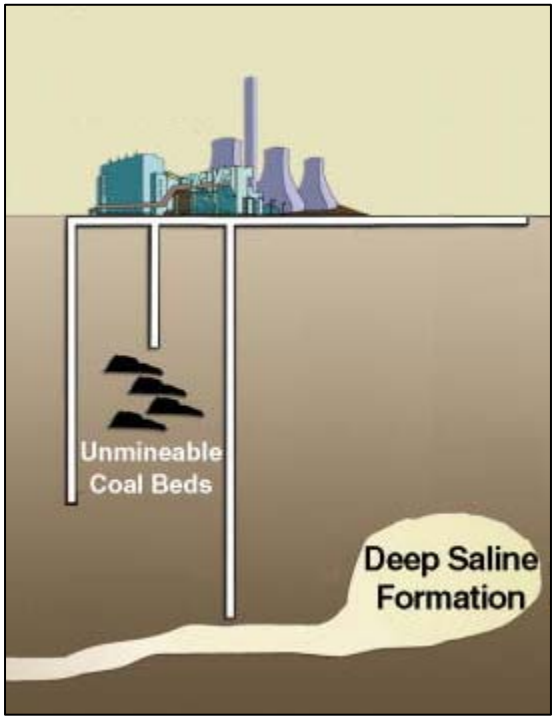
Major CO2 Electricity Generation Sources Located at Potential Geologic Sinks

State	Source Name	Sink Type: Coal Basin (USGS)	Sink Type: Saline Acquifer	Reg. Partnership CO2 (Tonnes)	Boiler ID	Boiler In Service Date	Boiler Gen Rating (MW)	NETL CO2 (Tons)
Pennsylvania	PPL MONTOUR	NO	YES	7,655,235	1	3/1/1972	806	4,547,162
					2	4/1/1973	819	5,037,507
	KEYSTONE	YES	YES	10,369,261	1	6/1/1967	936	6,661,229
					2	6/1/1968	936	6,289,448

Potential CCS Retrofit Sites – 145 GW

CCS Retrofit is most viable in coal-fired plants that:

1. Have an in-service date of 1967 or later
2. Generate 200 MW of electricity or greater
3. Are located directly over a potential geological sink (deep saline formation and/or unmineable coal seam)



Making retrofitting CCS on PC plants affordable is essential to addressing developing economies (China, India)

* Capture accounts for over 90% of cost for CCS

Final Observations

- Technology is available today for carbon capture from new and retrofitted coal-fired IGCC and PC power plants, however:
  - It is very expensive
  - Parasitic load is very 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)
  - CCS Integration and Risk Sharing (CCPI, FutureGen Restructured)
- Deployment Incentives (e.g., Tax Credits and Loan Guarantees)