NATIONAL ENERGY TECHNOLOGY LABORATORY

# DOE Perspective on Coal CCS

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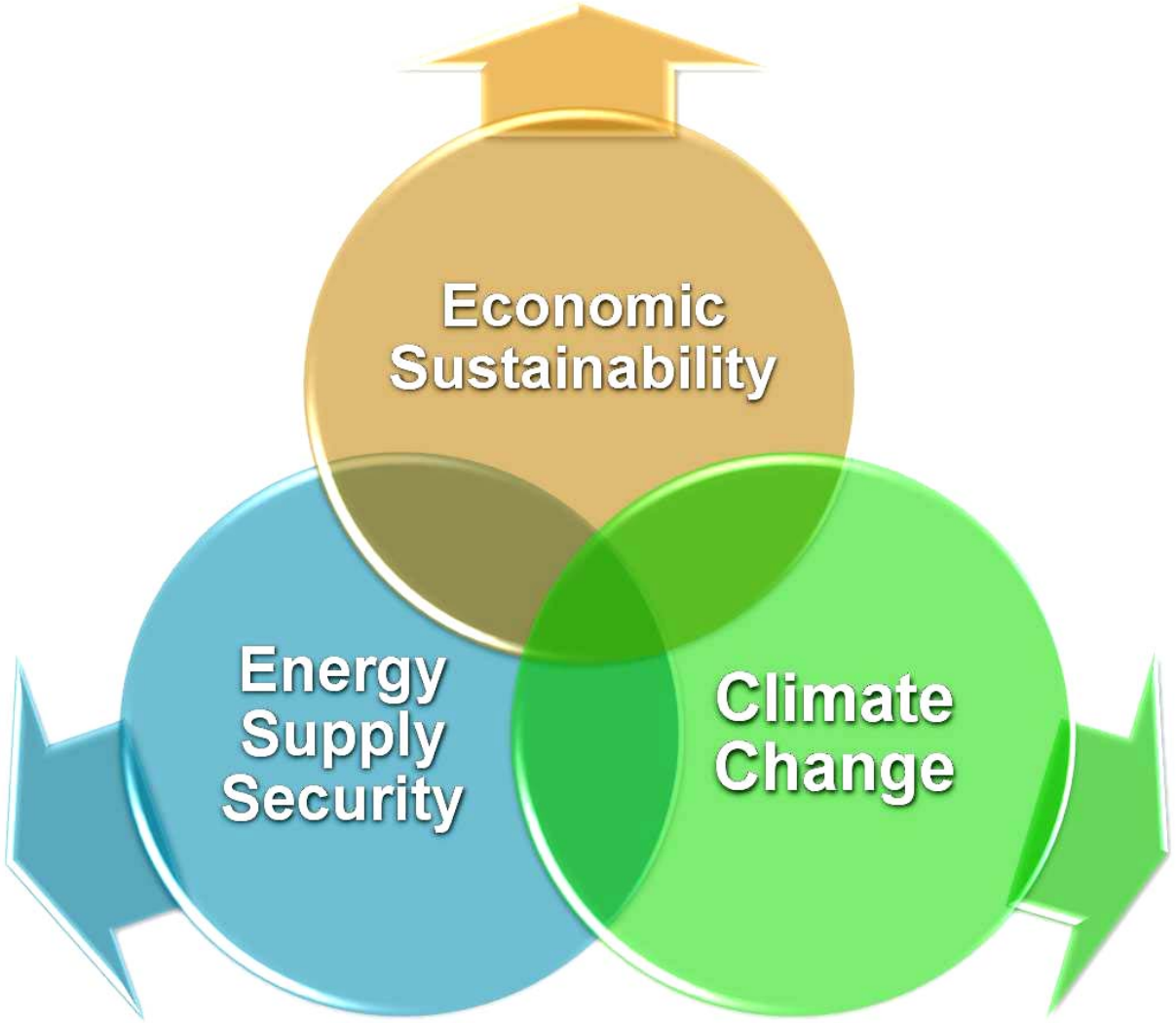
Chief Technology Officer

# Energy Strategy Complexity



# Observations from $CO_2$-Energy Modeling

- Economy wide, the majority of carbon emission reductions over the next several decades are expected to occur in the electric power sector, primarily from reduced use of conventional coal plants.
- Model predictions of reductions in coal use are sensitive to the relative pricing of coal with CCS vs. nuclear, and assumptions for demand reductions through energy efficiency.
- Internal DOE analysis indicates that coal with CCS (and to a lesser extent gas with CCS) will contribute significantly to our electricity supply in 2030.
- Looking out on a path to long-term stabilization at 450ppm $CO_2$ (~ 519 to 558ppm $CO_2$-e), modeling by DOE's shows that coal with CCS and gas with CCS continue to play a role in 2050 and beyond.
- The availability of CCS and nuclear technologies have a significant impact on allowance prices; these technologies must be developed, demonstrated, and deployed on a large scale before 2030.

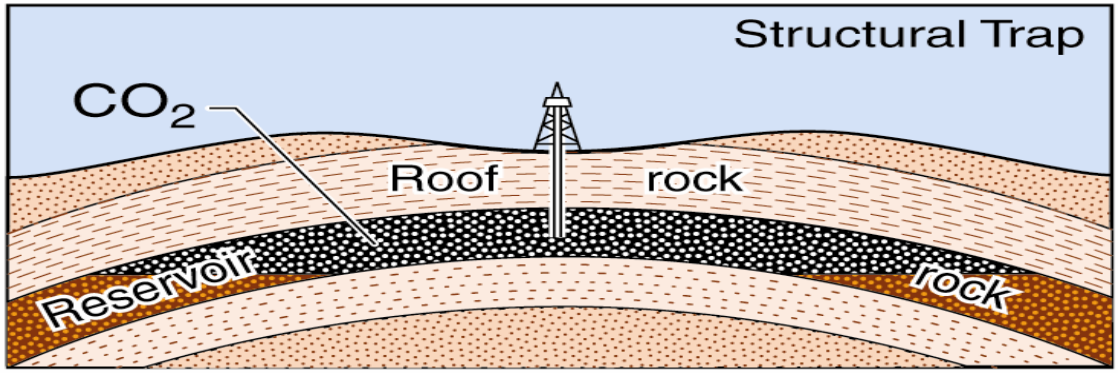
# CCS Experience

- **Carbon capture technology is commercially available**
  - Post-combustion capture at 20-80 MWe
  - Pre-combustion (gasification) capture at full scale
- **$CO_2$ injection into geologic formations is widely practiced today**
  - EOR: 48 million TPY in 2007
  - 50 Acid gas injection projects
  - Megaton/yr injection projects
    - Weyburn-Midale
    - Sleipner
    - In Salah




*Photo sources: E.S. Rubin, Carnegie Mellon, Statoil*

# Carbon Storage Mechanisms




- ***Physical trapping***
- ***Residual phase trapping***
- ***Solution Trapping***
- ***Mineralization***

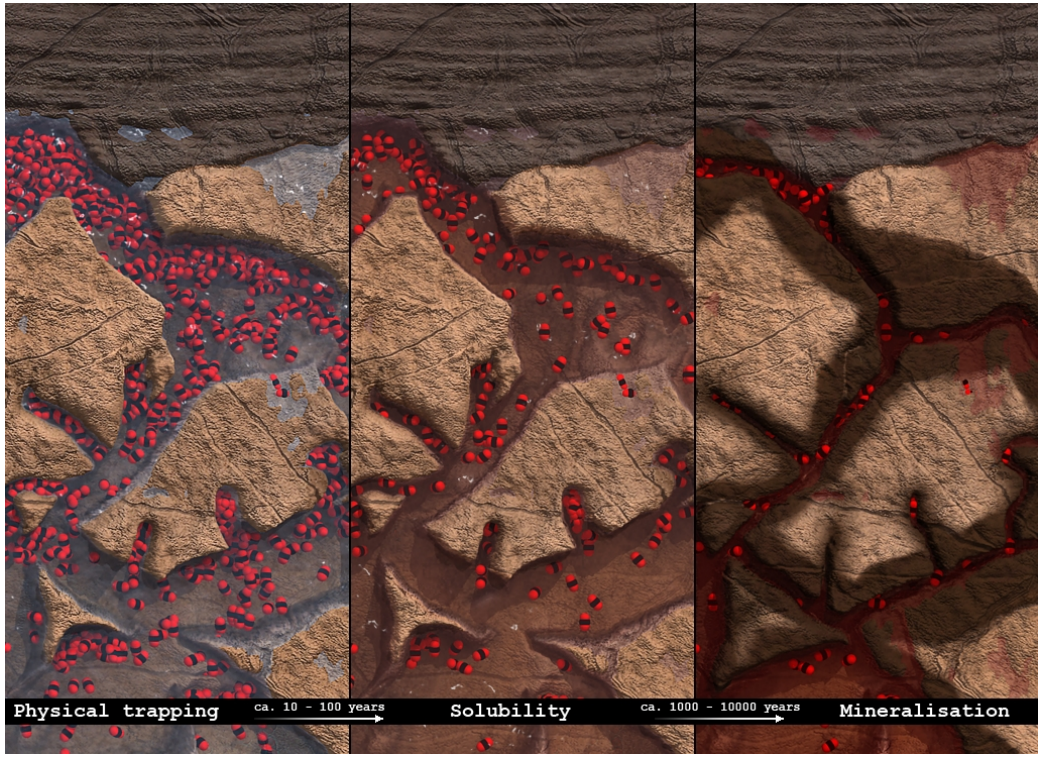


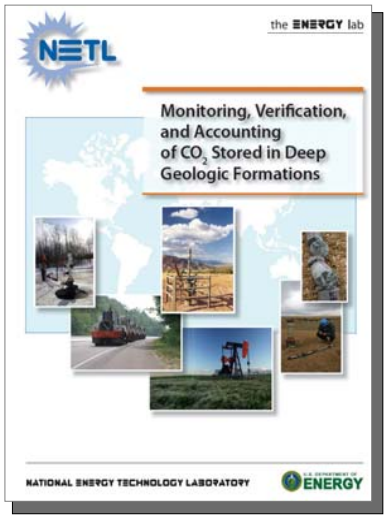


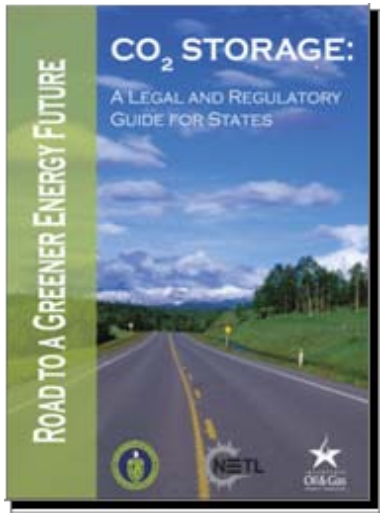

*Photo courtesy of www.bellona.org*

# Key Challenges for CCS

## Technical Issues

- **Capture Technology**
  - Existing Plants
  - New Plants (PC)
  - IGCC
- **Cost of CCS**
- **Sufficient Storage Capacity**
- **Permanence**
- **Best Practices**
  - Storage Site Characterization
  - Monitoring/Verification
  - Modeling




## Legal/Social Issues

- **Regulatory Framework**
  - Permitting
  - Treatment of $CO_2$
- **Legal Framework**
  - Liability
  - Ownership
    - Pore space
    - $CO_2$
- **Infrastructure**
- **Human Capital**
- **Public Acceptance**

# Regional Carbon Sequestration Partnerships

- *Engage regional, state, and local governments*
- *Determine regional sequestration benefits*
- *Baseline region for sources and sinks*
- *Establish monitoring and verification protocols*
- *Address regulatory, environmental, and outreach issues*
- *Validate sequestration technology and infrastructure*

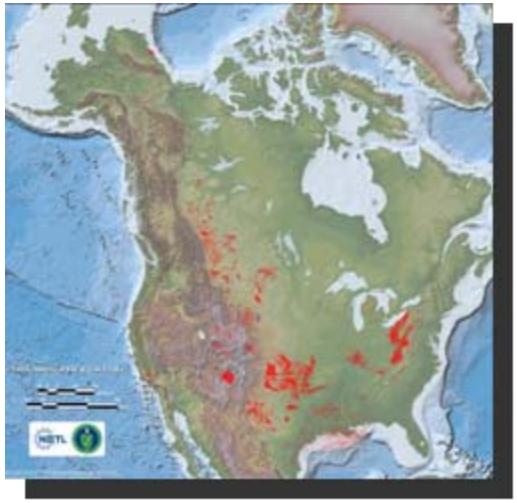
- *7 Regional Partnerships*
- *43 States, 4 Canadian Provinces*
- *350+ distinct organizations*

***Developing the Infrastructure for Wide-Scale Deployment***

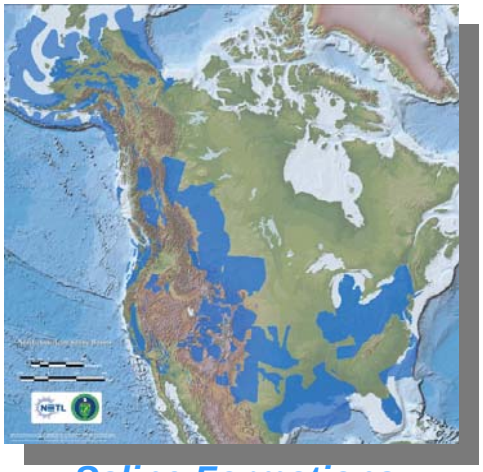
# National Atlas Highlights (Atlas II)

## *Adequate Storage Projected*

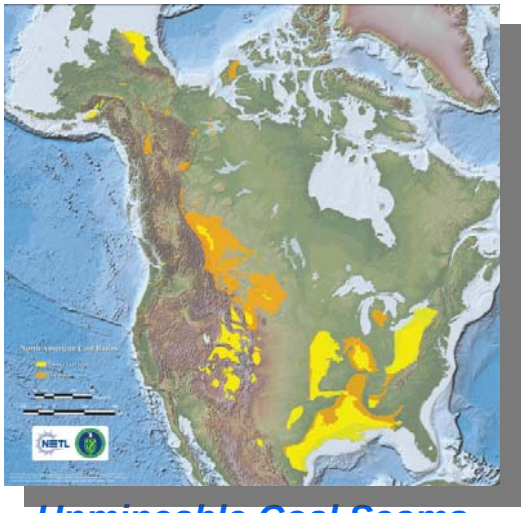
***Emissions ~ 3.8 GT $CO_2$/yr point sources***



***Oil and Gas Fields***



***Saline Formations***



***Unmineable Coal Seams***

***North American $CO_2$ Storage Potential (Gigatons)***

***Conservative Resource Assessment***

| Sink Type | Low | High |
|---|---|---|
| Saline Formations | 3,300 | 12,600 |
| Unmineable Coal Seams | 160 | 180 |
| Oil and Gas Fields | 140 | 140 |

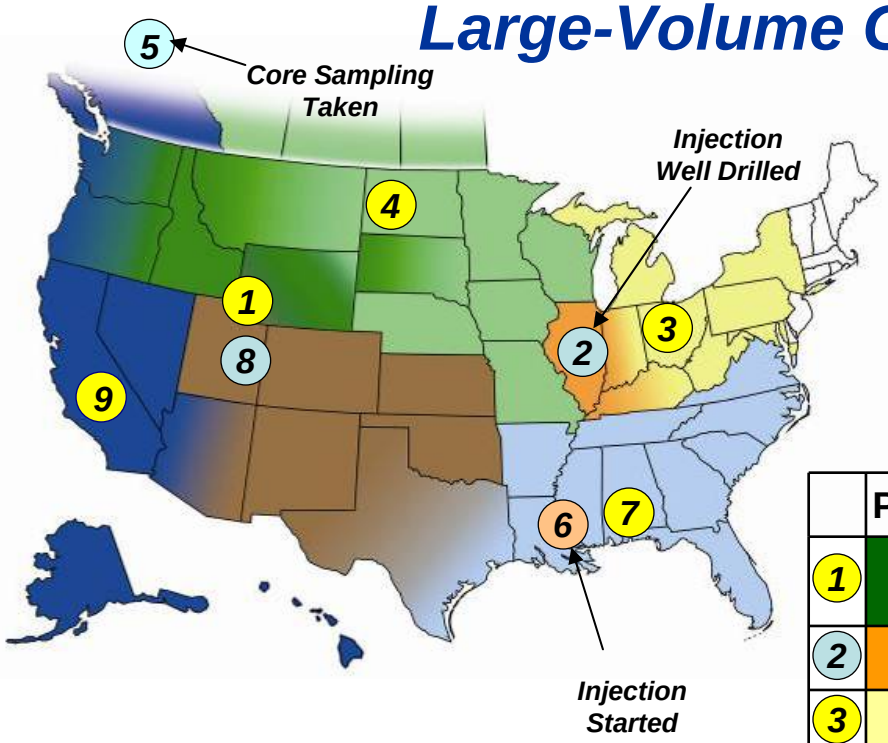
***Hundreds of Years of Storage Potential***



*Download at http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasII/atlasII.pdf*

# RCSP Phase III: Development

## *Large-Volume Geologic Field Tests*



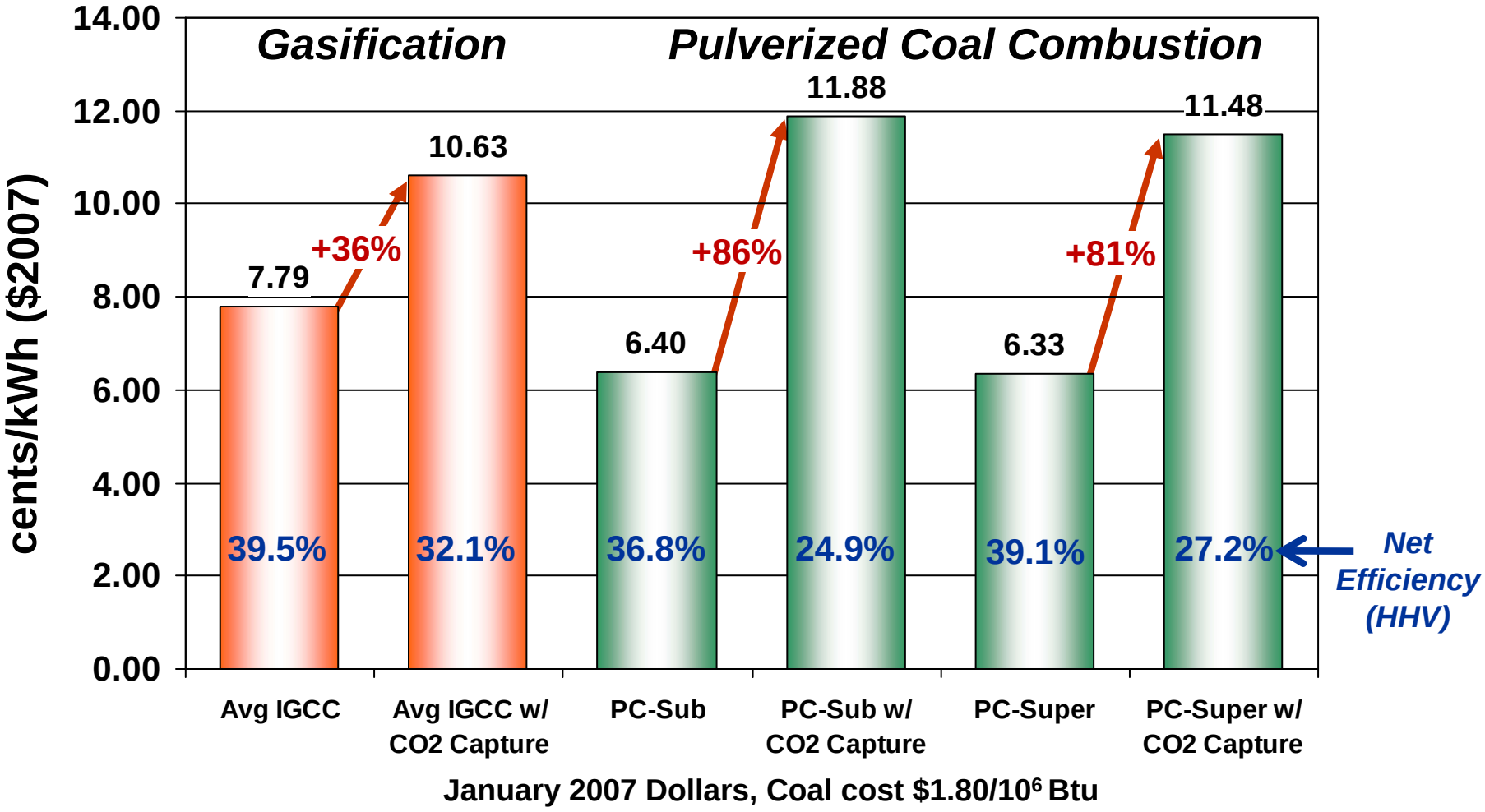

- ✓ *Nine large-volume tests*
- ✓ *Injections initiated 2009 – 2011*

| | Partnership | Geologic Province | Type |
|---|---|---|---|
| 1 | Big Sky | Triassic Nugget Sandstone / Moxa Arch | Saline |
| 2 | MGSC | Deep Mt. Simon Sandstone | Saline |
| 3 | MRCSP | Shallow Mt. Simon Sandstone | Saline |
| 4 | PCOR | Williston Basin Carbonates | Oil Bearing |
| 5 | | Devonian Age Carbonate Rock | Saline |
| 6 | SECARB | Lower Tuscaloosa Formation Massive Sand Unit | Saline |
| 7 | | | |
| 8 | SWP | Regional Jurassic & Older Formations | Saline |
| 9 | WESTCARB | Central Valley | Saline |

- *2009 Injection Scheduled*
- *2010 Injection Scheduled*
- *2011 Injection Scheduled*

# Cost of Electricity Comparison -- New Plants

## *(NETL Baseline Study)*








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

# DOE Coal RD&D Program

- **Overall Coal Program goal (deployment in 2020):**

  >90% $CO_2$ capture

  <10% increase in cost of electricity (COE) with CCS

- **Sequestration Program goal (2012):**

  ✓ 90% $CO_2$ capture

  ✓ 99% storage permanence

  ✓ < 10% increase in COE (*new plants -- pre-combustion capture)*

  ✓ < 35% increase in COE *(existing plants -- post- and oxy-combustion)*

  ✓ ±30% storage capacity estimates

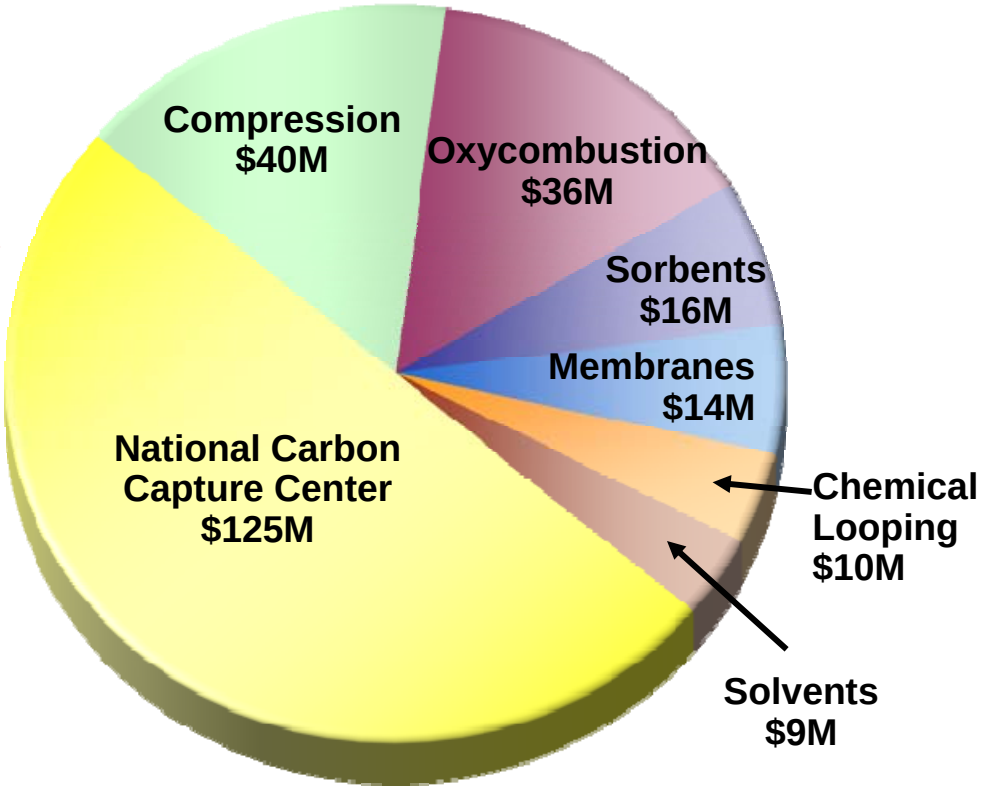
# Coal – CCS RD&D Budget

## Total FY 2009 Program Funding: $692 M

- Sequestration: $150 M
- Existing Plants: $50 M
- Gasification: $65 M
- Turbines: $28 M
- Fuel Cells: $58 M
- Fuels: $25 M
- Advanced Research: $28 M
- CCPI: $288 M
- FutureGen: $0 M

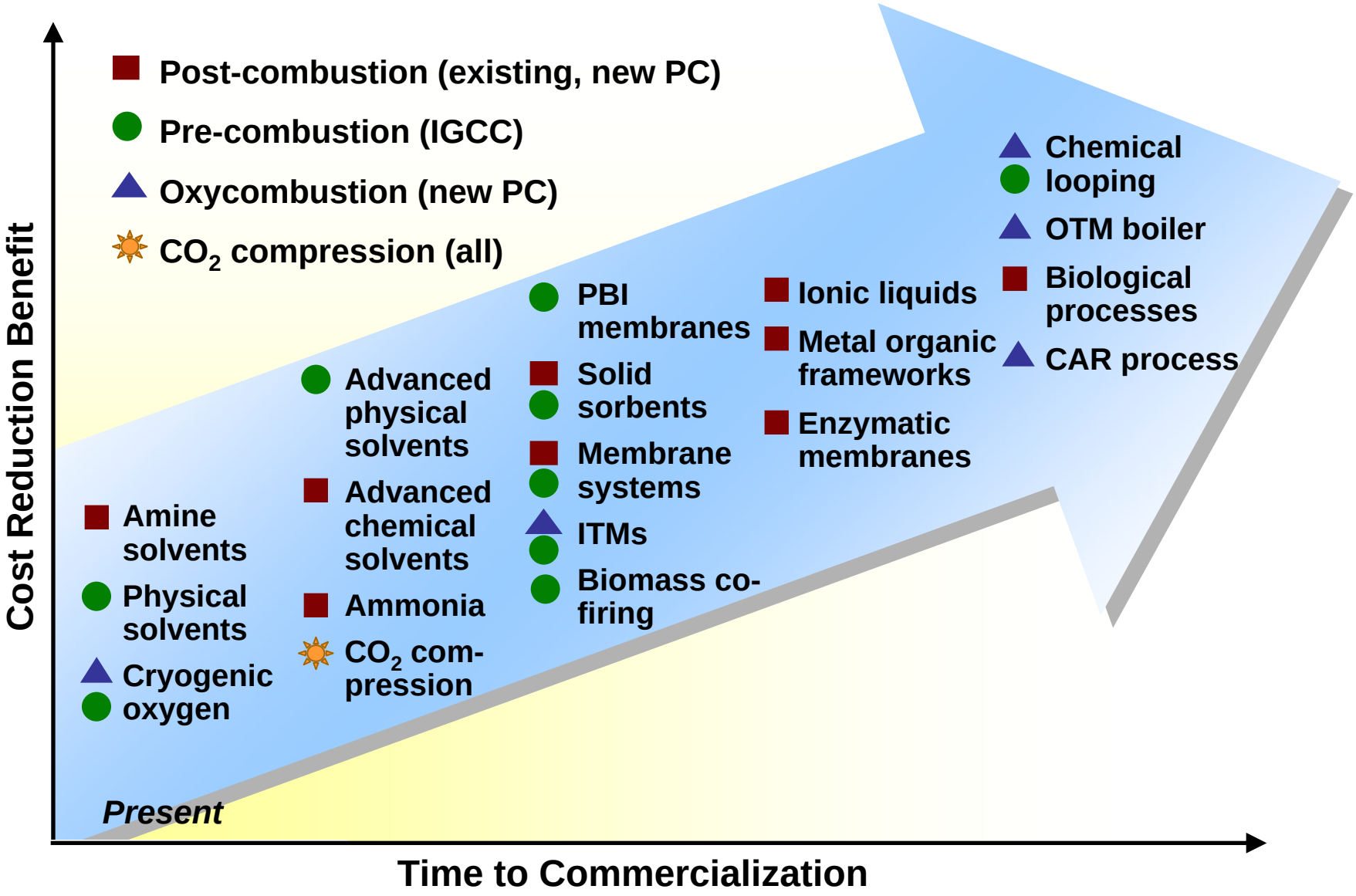
## *Existing Plants Portfolio*

*(Multiyear)*




***27 Active Projects***
***Total Value = $250M***
***DOE Share = $170M***

# Advancing Carbon Capture Technologies



# Clean Coal Power Initiative Round 3
## *(CCPI-3)*

- **Objective**
  - Demonstrate coal-based technologies that capture & sequester, or put to beneficial reuse, $CO_2$ emissions at commercial scale
- **Requirements**
  - Pre-combustion, post-combustion, oxy-combustion
  - Geologic storage in saline aquifer, EOR, coal seams, basalt, stacked storage
  - $\geq$ 300,000 tons $CO_2$ per year
  - *1st closing date - Jan 20, 2009*
    - *Capture > 90%; Coal use > 75%*
  - *2nd closing date - Aug 24, 2009*
    - *Capture > 50%, target 90%; Coal use > 55%*
  - Targeting COE increases of
    - *< 10% for gasification; < 35% for combustion & oxy-combustion*
- **Status**
  - $1.436 billion available, including $800 million in ARRA funds
  - 1st group of applications received Jan 20, 2009
    - ***Two selections made in June 2009***
  - 2nd group of applications due Aug 24, 2009

# CCPI-3: Hydrogen Energy International

## *IGCC with Hydrogen Turbine and Full Integrated CCS*

- **257 MWe (net) IGCC in Kern County, CA**
- **90% $CO_2$ capture**
- **2 million TPY sequestered in EOR**
- **$2.6 billion (DOE $308 million)**
- **Construction starts, March 2011**
- **Demonstration starts 2015**

# CCPI-3: Basin Electric Power Cooperative

## *Post-Combustion $CO_2$ Capture and Sequestration*

- **Antelope Valley Station (AVS) near Beulah, ND**
- **120 MW-equivalent slipstream from AVS Unit 1**
- **90% $CO_2$ capture**
- **1 million TPY sequestered in EOR**
- **$300 million (DOE $100 million)**
- **Construction starts February 2010**
- **Demonstration starts January 2013**

# Fossil Energy Recovery Act Provisions

| *Fossil Energy ($ in Millions)* | *Funding Amount* |
|---|---|
| *Fossil Energy Research and Development* | *$1,000* |
| *Clean Coal Power Initiative – Round 3 FOA* | *$800* |
| *Industrial Carbon Capture Solicitation* | *$1,520* |
| *Geologic Formation Site Characterization* | *$50* |
| *Geologic Sequestration Training & Research* | *$20* |
| *Program Direction* | *$10* |
| *Total, Fossil Energy* | *$3,400* |

# American Recovery & Reinvestment Act of 2009

## *Industrial CCS ($1.52 B)*

- **Objectives**
  - Capture 75% of the $CO_2$ from the treated industrial stream
  - Store 1 million TPY of $CO_2$ in a saline formation or other value-added options
  - Investigate novel $CO_2$ use / reuse technologies
- **Planned Competitive Awards**
  - Large-Scale CCS Projects (1.32 B)
  - Innovative Concepts for Beneficial $CO_2$ Use ($100 M)
- **Staged Competition**
  - Phase I Project Feasibility/Definition
  - Competitive down-select after 7 months
  - Award Phase II projects by Sept. 30, 2010
  - Complete by September 2015
- **Cost Share**
  - Private cost share $\geq$ 20%
  - Target 50% for commercial scale projects,

# *FutureGen* Restart

- **New Limited Scope Cooperative Agreement** (7/09 – 3/10)
  - Preliminary Design, Revised Cost Estimate & Funding Plan
    - Rapid restart of preliminary design activities.
    - Completion of a site-specific preliminary design and updated cost estimate.
    - Expansion of the Alliance sponsorship group.
    - Development of a complete funding plan.
    - Potential additional subsurface characterization.
  - Key Deliverables
    - Revised cost estimate
    - Alliance funding plan
  - Estimated Cost $17.8 Million ($14.3 M DOE share)

- **Go/No-Go Decision 1/29/2010**
  - $1.073 Billion maximum DOE contribution for remainder of project
  - Project currently estimated at ~$2.4 Billion

# More Information on Our Websites

***NETL***
***www.netl.doe.gov***


***Office of Fossil Energy***
***www.fe.doe.gov***