Fossil Energy Sequestration Program

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2006 DOE Hydrogen Program Merit Review and Peer Evaluation Meeting

May 16, 2006
Temperature and CO₂ Linked

Current Concentration Levels ~ 380 ppmv

“Historical CO₂ Record From the Vostok Ice Core” J.M. Barnolo et al. August 1999

http://cdiac.esd.ornl.gov/pns/current_ghg.html

Oak Ridge National Laboratory Current Greenhouse Gas Concentrations

http://cdiac.esd.ornl.gov/ftp/trends/co2/vostok.icecore.co2
U.S. Emissions of GHG Under the Reference and Stabilization Scenarios

By 2050 the gap equals 5,300 MMmtCO2/yr
Technological Carbon Management Options

Reduce Carbon Intensity
- Renewables
- Nuclear
- Fuel Switching

Improve Efficiency
- Demand Side
- Supply Side

Sequester Carbon
- Capture & Store
- Enhance Natural Sinks

All options needed to:
• Affordably meet energy demand
• Address environmental objectives
What is Carbon Capture

Separation and concentration of CO₂ from flue streams:

Three general classes of capture technology:

- Post-combustion (e.g., amine scrubbing; adv. membranes)
- Pre-combustion (e.g., H₂O-gas shift; hydrate separation)
- Oxy-firing combustion (recirculation of the flue stream)

Very expensive (40-80% in C.O.E.)

Primary research goal – cost reduction
What is Sequestration

**Geologic**
Placement of CO₂ into an underground formation where it will remain isolated from interactions with the Earth’s atmosphere for hundreds to thousands of years.

**Terrestrial**
Enhancement of the uptake of CO₂ by plants that grow on land and in freshwater as well as enhancement of carbon storage in soils.
Carbon Storage – How does it work?

Storage mechanisms vary by target class; generally multiple processes which improve over time

Physical trapping
- Impermeable cap rock
- Either geometric or hydrodynamic stability

Residual phase trapping
- Capillary forces immobilized fluids
- Sensitive to pore geometry (<25% pore vol.)

Solution/Mineral Trapping
- Slow kinetics
- High permanence

Gas adsorption
- For organic minerals only (coals, oil shales)
Sequestration Program Statistics FY2006

Strong industry support
~ 39% cost share on projects

Federal Investment to Date
~ $260 Million

Diverse research portfolio
~ 70 R&D Projects

FY 2006 Budget:
- Regional Partnerships: 27%
- Capture of CO2: 19%
- Sequestration: 12%
- MMV: 11%
- Crosscutting: 10%
- Congressionally Directed Projects: 15%
- Non-CO2 GHG Mitigation: 1%
- Breakthrough Concepts: 5%

FY07 Pres. Req. $73.971 Million
Sequestration Program Goals

*Develop Technology Options for GHG Management That...*

- **Are safe and environmentally acceptable**
- **Separation and Capture R&D Goals**
  - 2007 have two technologies < 20% increase in Cost of Energy
  - 2012 developed two technologies < 10% increase Cost of Energy
- **Sequestration/Storage R&D Goals**
  - 2012 predict CO₂ storage capacity with +/- 30% accuracy
  - Develop best practice reservoir management strategies that maximize CO₂ trapping
- **Monitoring, Mitigation & Verification**
  - 2012 ability to verify 95% of stored CO₂ for credits (1605b)
  - CO₂ material balance to >99%

### Cost Performance Goals

<table>
<thead>
<tr>
<th>Year</th>
<th>COE Penalty IGCC Plants (% Increase)</th>
<th>COE Penalty PC Plants (% Increase)</th>
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<tbody>
<tr>
<td>2002</td>
<td>30</td>
<td>80</td>
</tr>
<tr>
<td>2007</td>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>2012</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>2015</td>
<td>&lt;10</td>
<td>10</td>
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<tr>
<td>2018*</td>
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<td>0</td>
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*Cost/Energy offset from sequestering CO₂ with criteria pollutants NOX, SOx, H2S (gasification)

*** technologies identified and ready to move to demonstration (~ 4yrs) 
and then deployment (~4 yrs) – IGCC 20% and PC 45%
Carbon Sequestration Program Structure

**Core R&D**
- Capture of CO$_2$
- Sequestration
  - Direct CO$_2$ storage
  - Enhanced natural sinks
- Monitoring, Mitigation, & Verification
- Non-CO$_2$ GHG Mitigation
- Breakthrough Concepts

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

**Integration**
- Power/Sequestration Complex
  - FutureGen
  - First-of-kind integrated project
  - Verify large-scale operation
  - Highlight best technology options
  - Verify performance & permanence
  - Develop accurate cost/performance data
  - International showcase

- **Initiated FY 2003**
- **Initiated FY 2004**
Regional Partnership Update
“Developing the Infrastructure for Wide Scale Deployment”

Phase I (Characterization)
- 7 Partnerships (40 states)
- 24 months (2003-2005)

Phase II (Field Validation)
- 4 years (2005 - 2009)
- All seven Phase I partnerships continued
- $100 million federal funds
- $45 million in cost share

Phase III (Deployment)
- 8 years (2009-2017)
- Large Scale Injection Tests
Phase I Highlights/Accomplishments

- Identified Thousands of Years of Storage Capacity during Characterization Phase
  - Coal Seams and Shales - ~ 18 GT
  - Oil and Gas Reservoirs - ~27 GT
  - Saline Formations - >5,000 GT

- Identified Value Added Products in Potential Sinks
  - Oil – 16 billion barrels of oil during sequestration in favorable fields
  - Coal Seams – 126 TCF CBM during sequestration in unmineable coal seams

- Created a Carbon Sequestration Atlas for the U.S.
  - NATCARB and Regional Atlases Available Online
  - www.natcarb.org
Regional Carbon Sequestration Partnerships
*Phase II Geologic Field Tests*

Injecting between 1,000 – 525,000 tons of CO₂

Over 300 Organizations
In Addition to Geologic - 10 Terrestrial Test
Example Phase II Project
WESTCARB

Rossetta-Calpine, Sacramento Valley, CA:

- Stacked sequestration EOR/Saline Aquifer test
- 2,000 tons CO₂ in a saline formation (end of 2006)
- 2,000 tons CO₂ in enhanced gas recovery scenario (end of 2007)
- 1.8 Gt CO₂ storage capacity in depleted gas fields in Sacramento Valley (128 fields)
- Estimated 140-840 Gt CO₂ storage capacity in saline formations in California, based on ten largest basins

Regional Partnerships Addressing Key Issues
- Geologic Capacity estimates
- Site selection criteria
- Reservoir modeling and validation
- Monitoring, Mitigation, and Verification (MMV)
- Operational considerations
- Economics of sequestration
Core R&D - Separation and Capture
Advanced Capture Technologies

Ionic Liquids\(^{(1)}\)
- Been discovered that CO2 is *highly soluble* in some ionic liquids
- Non-volatile liquid and high thermal stability
- Ability to capture SO2 with one solvent

Metal Organic Frameworks\(^{(2)}\)
- Highly porous materials
- Thermally stable
- High loading capacities
- Low manufacturing costs

Participants: UOP LLC\(^{(1)}\) and University of Notre Dame\(^{(2)}\)
Funding Opportunity Announcement in CO₂ Capture
DE-PS26-06NT42829

‘Novel Technology and Commercially Focused Approaches to CO2 Capture and Separation for Existing and Future Carbon Based Electric Generation Power Plants’

Released: 4/19/2006
Closes: 6/16/2006 at 8:00 PM Eastern Time

Three (3) Areas of Interest

- **Breakthrough Approaches to Carbon Dioxide and Separation**
  - Novel and innovative methods (Post- and Oxy-combustion)

- **Continued Development of Direct CO₂ Capture and Separation Technologies**
  - Technologies continuing the development of post-, pre-, and oxy-combustion based CO₂ capture

- **Field-Testing of CO₂ Capture and Separation Technologies**
  - Conduct field-testing of oxygen-based combustion and post combustion CO₂ capture technologies

$39 Million DOE over 3-yrs, Cost-Sharing required of 20% of project costs

http://www.netl.doe.gov/business/solicitations/index.html#42829
Sequestration Core R&D
Frio Brine Reservoir Pilot Test
Univ. of Texas Bureau of Economic Geology

- Investigated injectivity, safety, capacity and permanence of CO₂ for Gulf Coast saline reservoir

Phase I (Oct 2004 injection):
- demonstrated 1600 tons CO₂ injection at 5100 ft in a brine reservoir without adverse health, safety, or environmental effects;
- determined the distribution of injected CO₂ using diverse monitoring technologies;
- demonstrated validity of models; and
- developed expertise necessary for success of large-scale CO₂ injection

Phase II will follow these successes and inject ~700 tons CO₂ into unperturbed lower Frio sandstone unit using existing injection and observations wells; based on experience, study will:
- develop effective monitoring strategy with geophysics, geochemistry, logging, and reservoir properties
- refine reservoir modeling
- develop best practices

Participants: Texas BEG, BP, Schlumberger, Texas American Resources, Praxair, Core Labs, Sandia Technologies, LBNL, LLNL, ORNL, NETL
MMV Core R&D
IEA GHG Weyburn CO₂ Monitoring and Storage Project

- Weyburn field EOR flood operations inject CO₂ into carbonate oil reservoir at 5000 ft depth; integrated with CO₂ storage study
- CO₂ (with H₂S) is piped 204 miles from Dakota Gasification Plant
- Results for CO₂ reduction:
  - 5000 tons/day of CO₂ stored in ground
  - more than 5 million tons already injected
  - storage potential of 30 million tons of CO₂
- Results for oil increase:
  - additional 10,000 barrels/day
  - oil production potential of additional 130 million barrels

Phase II:
- expand to the Midale Unit operated by Apache Canada Ltd. who will implement a field-wide CO₂ EOR project in 2005
- expand studies of characterization, monitoring and verification, reservoir performance, modeling, environmental impacts, and risk assessment
- develop a “Best Practices Manual” for geological storage, monitoring, and verification
Additional Information