The U.S. Department of Energy/National Energy Technology Laboratory’s Carbon Dioxide Capture R&D Program

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Carbon Capture Program
Pulverized Coal Power Plant System

*Post-combustion CO₂ Scrubbing*

**Post-combustion advantages:**
- Back-end retrofit
- Slipstream (0 to 90% capture)

**Amine scrubbing Advantages:**
- Proven Technology (Petroleum refining, NG purification)
- Chemical solvent → High loadings at low CO₂ partial pressure
- Relatively cheap chemical ($2-3/lb)

**Key Challenges:**
- Dilute flue gas (12-15 volume %)
- 2-3 MM acfm for a 500-600 MWe plant
- ~50% currently scrubbed for SOx/NOx
- Increased cooling requirements
IGCC Power Plant System

Pre-combustion CO$_2$ Scrubbing

IGCC CO$_2$ Capture Advantages:
- High chemical potential (Temp, $P_{CO_2}$)
- Low Volume Syngas Stream

Selexol™ CO$_2$ Capture Advantages:
- 30+ years of commercial operation (55 worldwide plants)
- Physical Liquid Sorbent
- Highly selective for H$_2$S and CO$_2$
- CO$_2$ is produced at “some” pressure

Key Challenges:
- Complex, integrated power process
- Additional process (WGS) to get high capture rates
- Current technology (Selexol) requires cooling and reheating
Pulverized Coal Oxyfuel Combustion
Technology Opportunities

Coal + O₂ → CO₂ + H₂O

Cheap Oxygen
Oxygen Membranes

ASU

95-99% O₂

PC Boiler (No SCR)

Steam

Power

Recycle Compressor

Wet Limestone FGD

ID Fans

CO₂

CO₂ Compression (15 – 2,200Psia)

Advanced MOC*
Reduce CO₂ Recycle
Handle High Sulfur Con.

Advanced Compression
Ramgen, SwRI

Oxyfuel Boilers
Compact Boiler Designs
Adv. Materials (USC)
Advanced Burners

Co-Sequestration
Multi-pollutant capture

*Materials of Construction
Deployment Barriers for CO₂ Capture On New and Existing Coal Plants Today

1. Scale-up
   • Current Post Combustion capture ~200 TPD
   • 550 MWe power plant produces 13,000 TPD

2. Energy Penalty
   • 20% to 30% less power output

3. Cost
   • Increase Cost of Electricity by 80%
   • Adds Capital Cost by $1,500 - $2,000/kW

4. Regulatory framework
   • Transport — pipeline network
   • Storage

5. Economies of Scale
   – Land, power, water use, transportation, process components, …
Scale-Up Is An Issue

- **Laboratory Scale**
  - 0.1 ft³ Reactor Volume
  - 0.27 scf per minute

- **550 MWe Scale**
  - 57,000 ft³ Reactor Volume
  - 2,000,000 scf per minute

**Technically Possible?**

**Economically Feasible?**
Stages of Energy RD&D

DOE Research Programs

Basic Research
- Office of Science Research

Applied Research
- Fossil Energy Advanced Research

Process & Engineering Development
- Fossil Energy Core Programs

Demonstration & Commercialization
- CCPI, ICCS, FutureGen

Research Phases

Bridges basic research & technology development programs
### DOE/NETL CO₂ Capture RD&D

#### R&D Programs

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#### Demonstration Programs

- Clean Coal Power Initiative
- FutureGen 2.0
- Industrial Carbon Capture and Storage
## Budget

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Carbon Dioxide Capture R&D Projects

**Pre-Combustion**
- **Laboratory/Bench Scale**
  - < 0.5 MWe
  - Simulated or real syngas
  - 1 Solvent
  - 2 Solid Sorbents
  - 7 Membranes
- **Pilot-Scale**
  - < 0.1 MWe
  - Coal derived syngas *
  - MTR CO₂ Membrane
  - MTR H₂ Membrane
  - WPI H₂ Membrane
  - Parr Reactor Solvent

**Post-Combustion**
- **Laboratory/Bench Scale**
  - < 0.5 MWe
  - Simulated or real flue gas
  - 15 Solvents
  - 9 Solid Sorbents
  - 7 Membranes
- **Pilot Scale**
  - 0.5 – 5 MWe
  - Coal flue gas
  - ADA Sorbent 1 MWe
  - MTR Membrane 1 MWe
  - Univ. KY Solvent 0.7 MWe
  - Southern Co. Solvent 1 MWe
  - Neumann Solvent 0.5 MWe
  - Linde Solvent 1 MWe

**Oxy-combustion**
- **Laboratory/Bench Scale**
  - < 0.5 MWe
- **Pilot Scale**
  - 0.5 – 5 MWe
  - Alstom Oxy-comb. 5 MWe
  - Jupiter Oxygen 5 MWe
  - Praxair OTM 1 MWe

**Compression**
- **Pilot Scale**
  - > 0.5 MWe
  - Ramgen 13,000 hp
  - SwRI 3,000 hp

* Indicates the use of coal derived syngas.
Pre-Combustion, Compression, Oxy-Combustion
National Carbon Capture Center at the Power Systems Development Facility (PSDF)  
Wilsonville, AL

Southern Company Services

- 3 MW – 35,000 lb/hr flue gas slip stream from post-combustion – from 880 MW Plant Gaston

- 6 MWe -100 tpd CO₂ – 20,000 lb/hr syngas from TRIG gasifier at PSDF

Offer a unique **flexible R&D facility** where processes can be tested on coal-derived gas at various scales
National Carbon Capture Center at the Power Systems Development Facility (PSDF)

**Goal**
Develop technologies under realistic conditions that will reduce the cost of advanced coal-fueled power plants with CO₂ capture

### Post-combustion

- **Plant Gaston**
  - 880 MWe
  - 12,000 tpd CO₂
  - FGD
  - ID Fan
  - Stack

  - **< 0.1 MWe**
    - Bench Scale Units
  - **< 2 tpd CO₂**
  - **1 MWe**
    - 20 tpd CO₂
    - Pilot Test Unit #2
  - **0.5 MWe**
    - 10 tpd CO₂
    - Pilot Solvent Test Unit #1

### Pre-combustion (IGCC)

- **Coal Gasification**
  - Baseline CO₂ Removal Process
  - Planned

  - **0.5 MWe**
    - 8 tpd CO₂
    - 1,500 pph Syngas
    - Bench Scale Test Units
    - Pilot Test Unit #2
  - **0.2 MWe**
    - 3 tpd CO₂
    - 500 pph Syngas
    - Pilot Test Unit #1
  - **1.5 MWe**
    - 25 tpd CO₂
    - 5,000 pph Syngas
    - Advanced CO₂ Removal Process

- **Transport Gasifier**
  - **6 MWe**
    - 100 tpd CO₂
    - 20,000 pph Syngas

- **Fixed and Fluid Beds**
  - Baseline CO₂ Removal Process
  - To Stack

- **Planned**
CO₂ Capture Program Goals

By 2020, have ready for demonstration, 2\textsuperscript{nd} generation technologies that achieve:

- **Post- and Oxy-combustion**
  - 90% CO₂ capture
  - Compression, transport, storage
  - < 35% increase in COE

- **Pre-combustion (IGCC)**
  - 90% CO₂ capture
  - Compression, transport, storage
  - < 10% increase in COE

**Market-Based Approach**

Putting CO₂ to Work – Carbon Utilization for Enhanced Oil Recovery
Carbon Capture Utilization and Storage (CCUS)

- **2\textsuperscript{nd} Generation CCUS technology will result in capture cost of <$40/tonne**
  - Satisfy strong EOR market opportunities
  - Meet broad acceptance
  - Enable a significant increase in domestic oil production.

- **Transformational CCUS technology will result in capture cost of <$10/tonne**
  - Open greater domestic EOR opportunities
  - Expand beneficial utilization opportunities such as conversion of CO₂ to higher value chemicals
  - Deliver advanced higher performance coal-fueled energy systems that can compete with NGCC
DOE/NETL CO₂ Capture RD&D Timeline

2010

2015

2020

2025

2030

R&D Phase

Demonstration Phase

1st Generation Ready for Deployment by 2020

2nd Generation Ready for Deployment

50+ MWe 2nd Generation Ready for Demo.

Demonstration of 1st Generation (CCPI)

5 - 25 MWe Pilot-Scale Field Testing of 2nd Generation

< 5 MWe Bench and Small Pilot-Scale 2nd Generation
Accomplishments

• **2012 FOA:** *Advanced Oxy-combustion Technology Development and Scale-up for New and Existing Pulverized Coal Power Plants*
  - Two-phase Investigation of Pressurized Oxy-combustion and Chemical Looping Combustion Systems
    - Phase I: Detailed Systems Analysis of Multiple Proposed Technologies
    - Phase II: Downselect Most Promising Systems for Component Development and Testing
  - **Closed April 17, 2012**
  - **Review in Progress**
  - **Announcement of Selections in August**
Accomplishments

• **Technology Readiness Level**
  – Developed in Response to GAO Recommendations
  – Levels Established Based on Scale, Degree of System Integration, and Test Environment in which the Technology has been Successfully Demonstrated
  – Assessment in Progress

• **Updated Carbon Capture Roadmap**
  – Under Development

• **Carbon Capture Program Accomplishments Report**
  – Accomplishments to Date for Pre-, Post-, and Oxy-Combustion Capture, Oxygen Production, and Compression
Looking Forward
FY2013 Pre-Combustion Capture Solicitation

• “Advanced Pre-combustion Carbon Capture Technology Development and Scale-up for Integrated Gasification Combined Cycle Power Plants”

• Fall 2012/Winter 2013- FOA scheduled for release

• Summer 2013 - Project selections

• Total funding available - ~$30 million

• Areas of Interest: TBD
Conference Overview

Monday
- Post-Combustion Membranes
- Post-Combustion Sorbents

Tuesday
- Post-Combustion Sorbents
- Post-Combustion Solvents

Wednesday
- Oxy-combustion and Oxygen Production
- Chemical Looping
- $\text{CO}_2$ Compression
- ARPA-E Capture Projects
- System Studies and Modeling

Thursday
- FutureGen 2.0, CCPI & ICCS Demonstrations
- Pre-Combustion Projects
Thanks for Participating!!

[Logos of various organizations]
For More Information About the NETL Carbon Capture Program

- NETL website: www.netl.doe.gov
- Office of Fossil Energy website: www.fe.doe.gov

Reference Shelf
- Annual CO2 Capture Meeting

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Innovations for Existing Plants

CO₂ Emissions Control

Capture CO₂ from Existing Coal Fired Power Plants (Apr. 2009)
Annual NETL CO₂ Capture Technology for Existing Plants R&D
Innovations Presentation - March 26-29, 2009
DOE/NETL's Monthly Carbon Sequestration Newsletter

Welcome to two Innovations for Existing Plants (IIP) Programs CO₂ emissions control R&D homepage. In FY08, the EP Program redirected its focus to include CO₂ emissions control for existing coal-fired power plants, e.g., conventional pulverized-coal-fired plants. The focus on CO₂ emissions control technology — both pre- and post-combustion — and related areas of CO₂ capture and CO₂ beneficial use is intended to support the industry's need for advancing technologies and options for the existing fleet of coal-fired power plants for meeting climate change goals. In addition to funding R&D activities, DOE/NETL also conducts in-house research to develop new breakthrough concepts for carbon capture that could lead to dramatic improvements in cost and performance relative to today’s technologies. The EP CO₂ emissions control R&D activity also sponsors systems analysis studies of the cost and performance of various carbon capture technologies. The program goal is to develop advanced carbon capture and separation technologies for existing power plants that can achieve at least 90% CO₂ removal at no more than a 20% increase in the cost of energy services.

Use the hypertext located in the adjacent blue box for time-edited interaction on the IIP CO₂ emissions control R&D activities. Information on pre-combustion CO₂ emissions control technology applicable to coal gasification-based (e.g., integrated gasification combined cycle) plants is located at the CO₂ Capture webpage of DOE/NETL’s Carbon Sequestration Program website.

Prior to FY08, DOE/NETL’s CO₂ emissions control R&D effort was conducted under the Carbon Sequestration Program. With responsibility for assessing plant CO₂ emissions control R&D now being conducted under the EP Program, the Carbon Sequestration Program continues to focus on pre-combustion CO₂ emissions control and geological sequestration. Since its inception in 1997, the Carbon Sequestration Program has been developing both core and supporting technologies through which carbon capture and storage (CCS) will become an effective and economically viable option for reducing CO₂ emissions from coal-fired power plants. Successful R&D will enable CCS research and development to address the policy and regulatory issues surrounding carbon dioxide sequestration in the most cost effective manner possible.