NATIONAL ENERGY TECHNOLOGY LABORATORY

Highlights of the DOE-Sponsored Major Carbon Sequestration Projects

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Presentation at the Association of Rural Electric Generating Cooperatives (AREGC) Annual Conference

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U.S. DEPARTMENT OF ENERGY

National Energy Technology Laboratory

Where Energy Challenges Converge and Energy Solutions Emerge

MISSION

Advancing energy options to fuel our economy, strengthen our security, and improve our environment

Albany, Oregon

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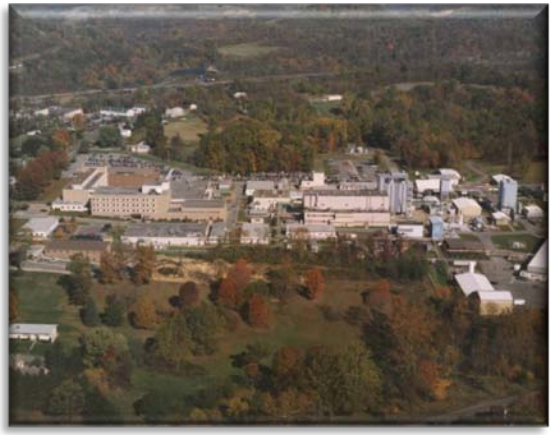
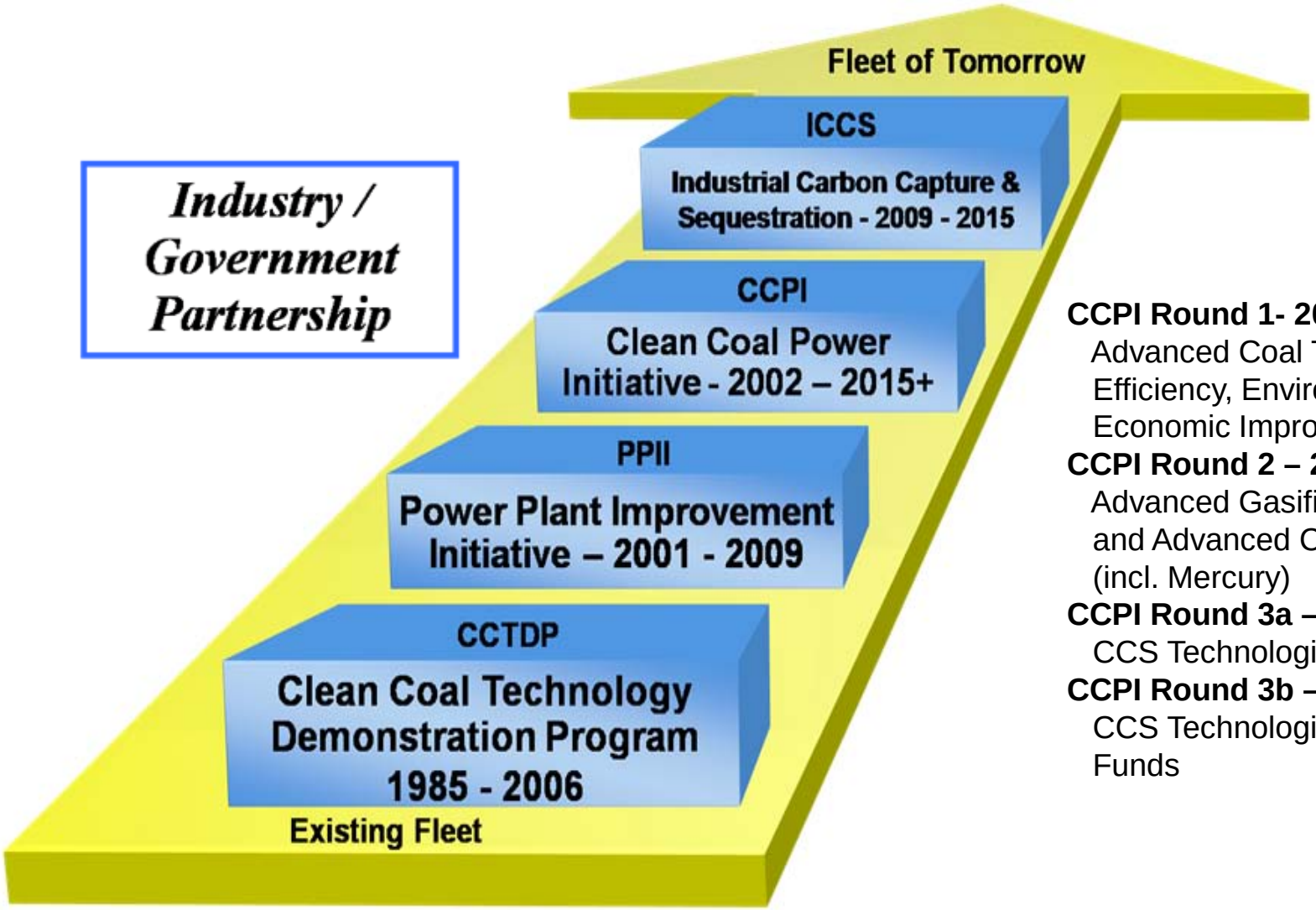


Morgantown, West Virginia

DOE's Major Demonstrations Program

A History of Innovative Projects



CCPI Round 1- 2002
Advanced Coal Technologies for Efficiency, Environmental, and Economic Improvements

CCPI Round 2 – 2004
Advanced Gasification Technology and Advanced Clean-up Systems (incl. Mercury)

CCPI Round 3a – 2008
CCS Technologies

CCPI Round 3b – 2009
CCS Technologies with ARRA Funds

Major Demonstration Program

Current Program Objectives and Targets

Clean Coal Power Initiative

- **CCPI-3**
  - Demonstrate the next generation technologies from coal-based electric power generating facilities that capture/sequester, or put to beneficial reuse, minimum of 300,000 tons per year of CO_2 emissions
  - Minimum coal or coal refuse energy input: 75% (Closing 1); 55% (Closing 2)
  - Attain 90% CO_2 capture efficiency in treated flue gas (Closing 1); 50% (Closing 2)
  - COE increase $\leq$ 10% for gasification; $\leq$ 35% for combustion & oxy-combustion (targets)

Industrial Carbon Capture and Sequestration

- **ICCS-Area 1**
  - Demonstrate advanced CCS technologies, at industrial sources, that may produce heat, fuels, chemicals, H_2 or other useful products with or without electricity production
  - Demonstrate sequestration with 1,000,000 tons per year of CO_2 emissions

What Is Carbon Sequestration?

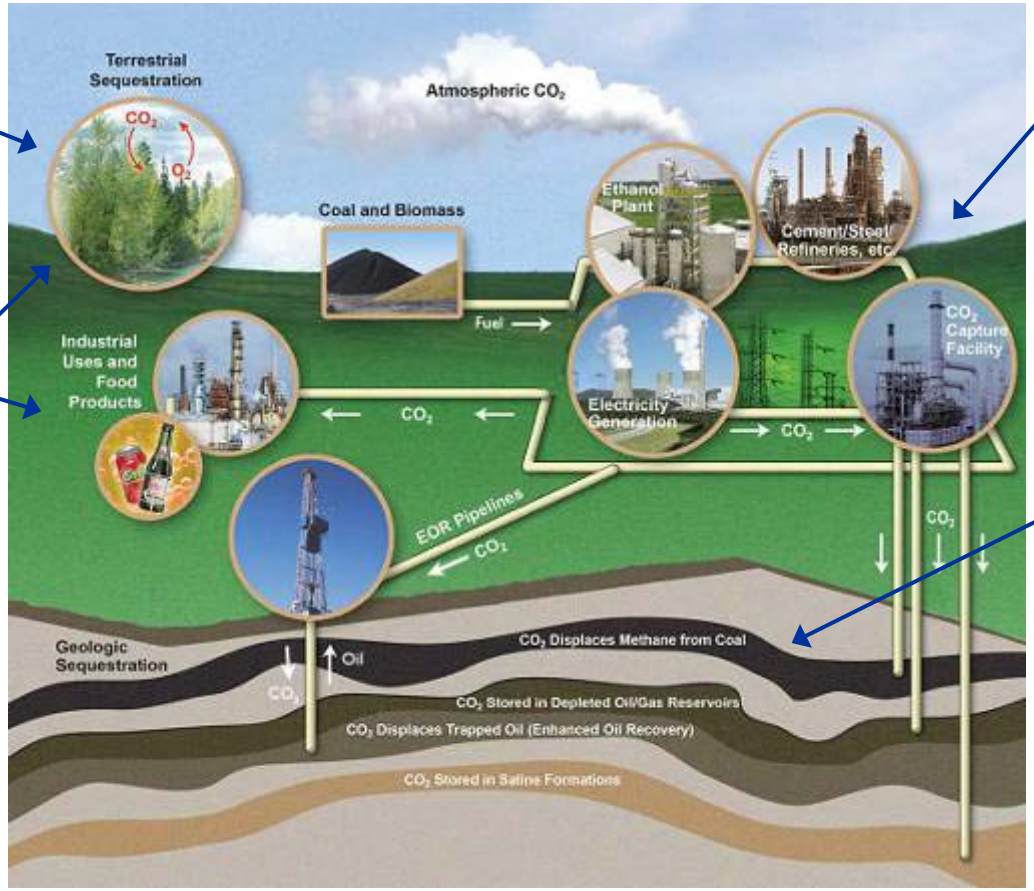
Capture and storage of CO_2 and other greenhouse gases that would otherwise be emitted to the atmosphere

Terrestrial Capture

CO_2 absorbed from air

Terrestrial Storage

Trees, grasses, soils



Point Source Capture

Power plants

Ethanol plants

Cement, steel, refineries

Natural gas processing

Geologic Storage

Saline formations

Depleted oil / gas wells

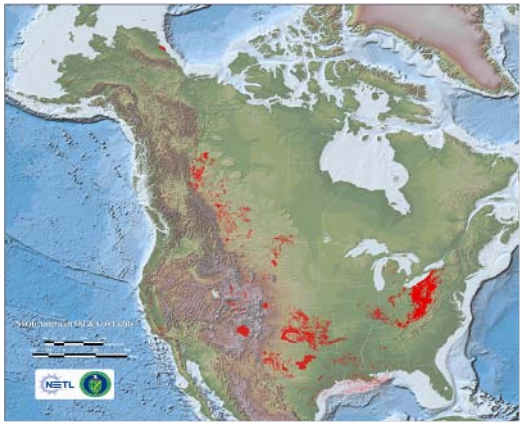
Unmineable coal seams

Basalts, shales, other

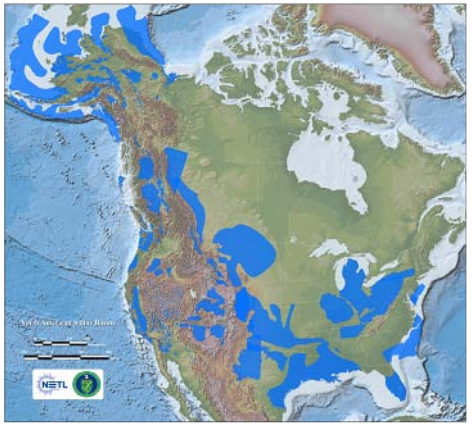
Sufficient Storage Capacity Emerging

National Atlas Highlights

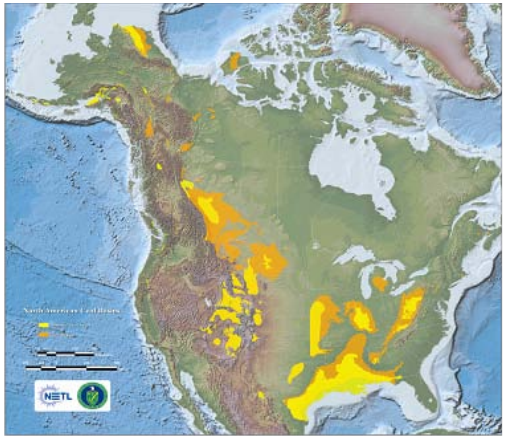
U.S. Emissions ~ 6 Billion Tons CO_2/yr all sources



Oil and Gas Fields



Saline Formations



Unmineable Coal Seams

North American CO_2 Storage Potential (Billion Metric Tons)

Conservative Resource Assessment

Sink Type	Low	High
Saline Formations	1,653	20,213
Oil and Gas Fields	143	143
Unmineable Coal Seams	60	117

Hundreds to Thousands of Years Storage Potential

Available for download at http://www.netl.doe.gov/publications/carbon_seq/refshelf.html

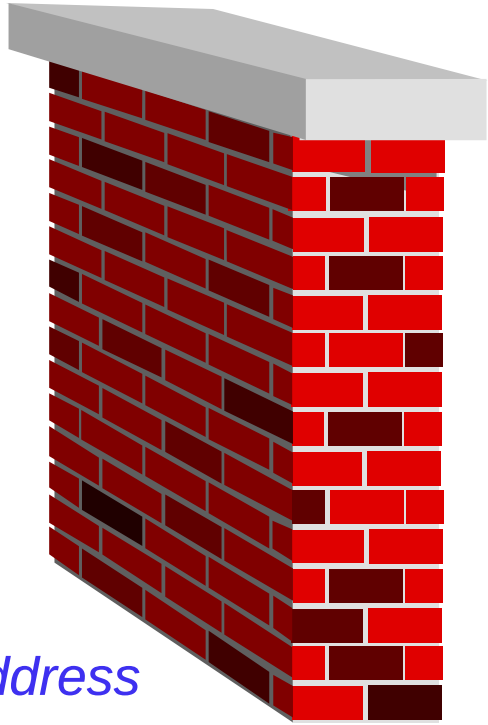
Key Challenges to Carbon Capture and Storage

Technical Issues

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

Legal/Social Issues

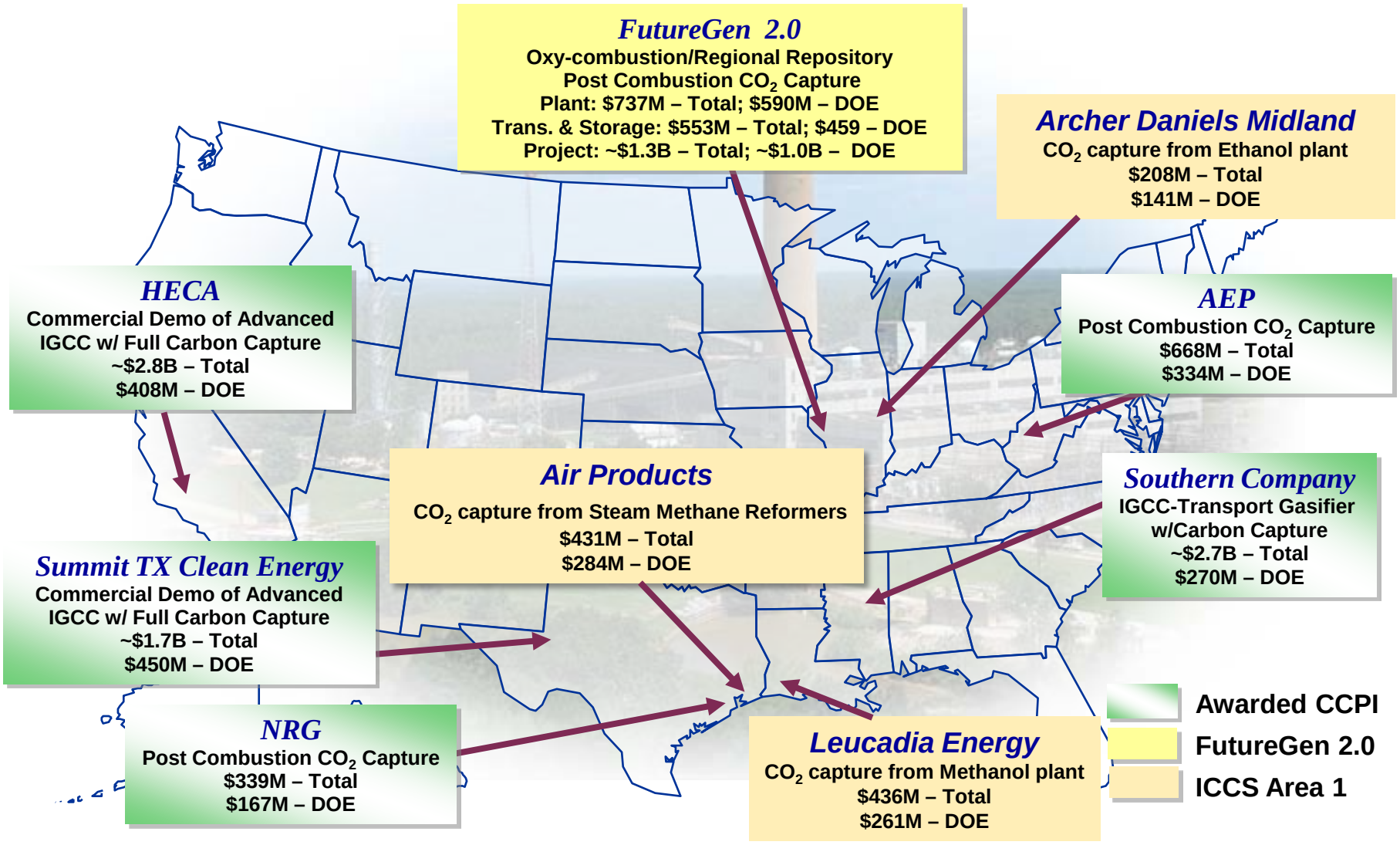
- **Regulatory Framework**
  - Permitting
  - Treatment of CO_2
- **Infrastructure**
- **Human Capital**
- **Legal Framework**
  - Liability
  - Ownership
    - pore space
    - CO_2
- **Public Acceptance (NIMBY → NUMBY)**



Large-Scale Projects helping to address both categories of issues

Active CCS Demonstration Projects

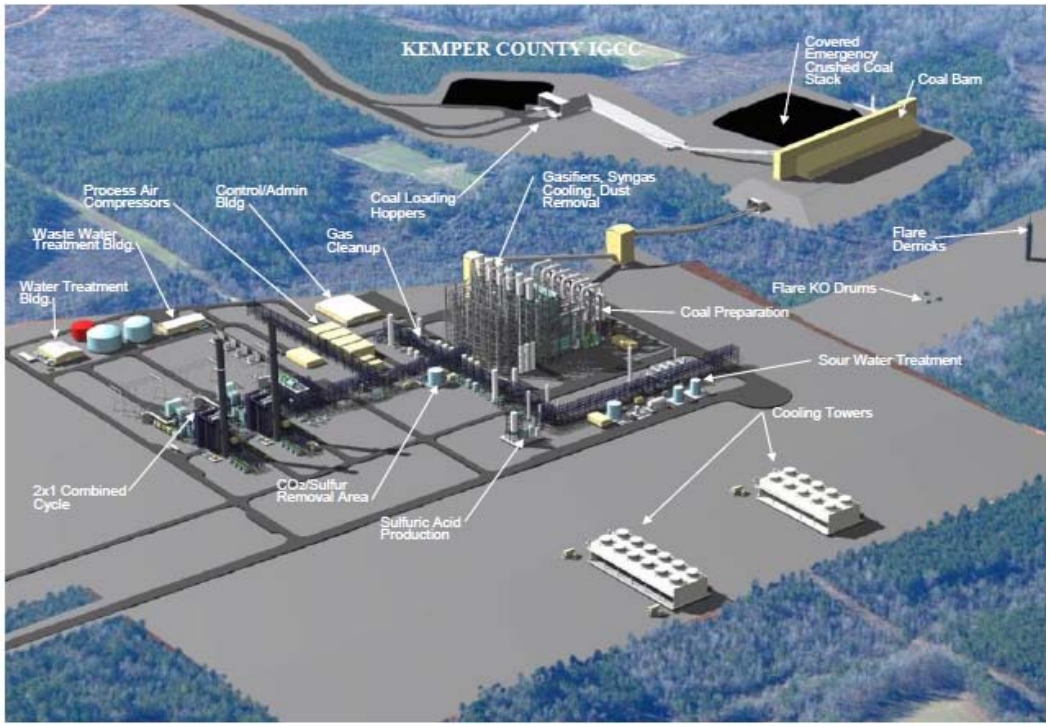
Locations & Cost Share



Southern Company Services, Inc.

Advanced IGCC with CO_2 Capture

- **Kemper County, MS**
- **582 MWe net IGCC facility**
  - KBR transport gasifiers (2)
  - Siemens Combustion Turbines (2)
  - Toshiba Steam Turbine (1)
- **~67% CO_2 capture**
  - Selexol® process
  - 3,000,000 tons CO_2 /year
- **EOR Sequestration site in Mississippi Oil Fields**
  - Start: 2014
- **Mississippi Lignite**
- **Total Project - $2.67 Billion**
  - DOE - $270 Million



- **Status**
  - Record of Decision completed
  - Construction in progress

Hydrogen Energy California

Advanced IGCC with CO_2 Capture

- **Kern County, CA**
- **~250 MWe (net) IGCC, 1.1 MT/yr Urea**
- **90% CO_2 capture - 2,000,000 tons CO_2/year**
- **EOR - Elk Hills oil field (Start: ~2016)**
- **Fuels**
  - Bituminous Coal/Petcoke
- **Maximize the use of non-potable water for power production**
- **Recycle all IGCC/project wastewater with 100% zero liquid discharge (ZLD) system**
- **Total Project ~ $2.84 Billion (DOE - $408 Million)**

IGCC Polygeneration with Integrated Carbon Capture & Sequestration

American Electric Power Co. (AEP) CCPI-3

Advanced Post Combustion CO_2 Capture

- **New Haven, WV**
- **235 MWe slipstream at AEP's 1300 MWe Mountaineer Plant**
- **90% CO_2 capture (Alstom Chilled Ammonia Process) 1,500,000 tons CO_2 /year**
- **Deep saline sequestration in the Rose Run and Copper Ridge formations (Start: 2015)**
- **Total Project - $668 Million (DOE - $334 Million)**
- **Status**
  - **FEED in progress**
  - **NEPA EIS in progress**

AEP's 1,300 MWe Mountaineer Supercritical Pulverized Coal Plant, New Haven, WV

W.A. Parish NRG Energy CCPI-3

Advanced Post Combustion CO_2 Capture

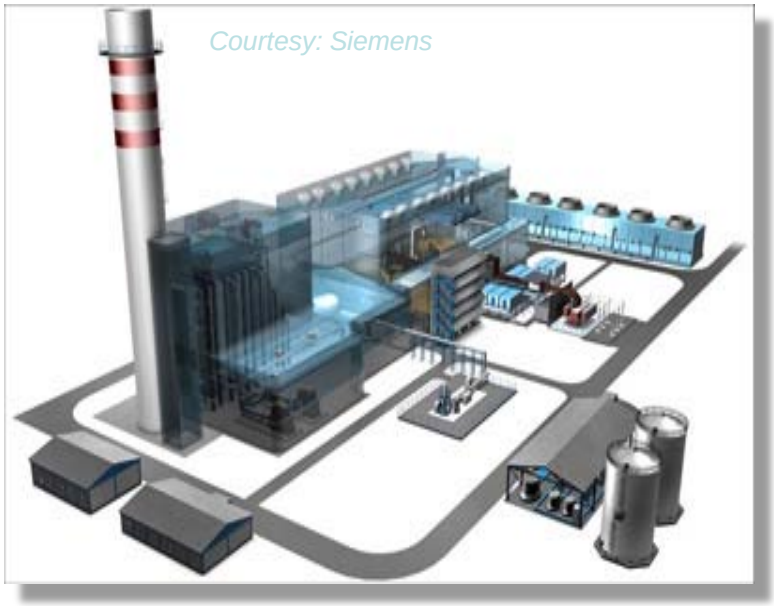
- **Thompsons, TX (near Houston)**
- **240 MWe slipstream at NRG Energy's W.A. Parish power plant**
- **PRB sub bituminous coal fuel**
- **90% CO_2 capture (Fluor's Econamine FG Plus^{SM} process) 1,400,000 tons CO_2/year from treated flue gas**
- **EOR in a Texas Gulf Coast oil field (Start: 2014)**
- **Total Project: $339 Million (DOE $167 Million)**
- **Status**
  - **60 MW FEED almost complete**
  - **Initiated 240 MWe FEED**
  - **Negotiations to purchase EOR host site ongoing**

NRG Energy's WA Parish plant

Summit Texas Clean Energy, LLC.

Advanced IGCC with CO_2 Capture

- **Penwell, Ector County, TX**
- **400 MWe (gross) Greenfield IGCC employing Siemens Gasification and Power Block – (2 Siemens gasifiers)**
- **PRB sub bituminous coal fuel**
- **90% CO_2 capture (Linde Rectisol ® Chilled Methanol Process) ~3,000,000 tons CO_2/year**
- **Permian Basin EOR w/sequestration in West Texas (Start: 2014)**
- **Total Project: $1.7 Billion**
  DOE Share: $450 Million
- **Status**
  - **FEED in progress**
  - **NEPA EIS in progress**



Poly-Gen Integrated Gasification Combined Cycle (IGCC) with full Carbon Capture & Sequestration

FutureGen 2.0

Oxy-combustion/Regional Repository

- **Meredosia, IL**
- **200 MWe (gross) oxy-combustion repowering of Ameren's Meredosia Unit 4 steam turbine (Start 2016)**
- **90% CO_2 capture (cryogenic separation) 1,300,000 tons CO_2 /year**
- **Deep saline sequestration in Mt. Simon formation. Preferred site is Morgan County, IL**
- **Total Project: $1.3 Billion**
- **DOE Share: $1.05 Billion**
- **Status**
  - **Pre-FEED in progress**
  - **Sequestration site characterization and validation**
  - **NEPA in progress**

Ameren's Meredosia Power Plant Meredosia, IL

Industrial CCS Project Objectives and Targets

Large-scale CCS from Industrial Sources (Area 1)
American Recovery and Reinvestment Act (ARRA) of 2009

Objectives

- Demonstrate advanced CCS technologies
- Integration with Monitoring, Verification & Accounting (MVA)
- Scope: FEED, Detailed Design, Construction, and Demonstration of Sequestration Operations

Target

- Industrial sources
- Industries may produce heat, fuels, chemicals, hydrogen or other useful products with or without electricity production
- One million tons/yr of CO_2 from each plant for CCS

Air Products and Chemicals, Inc. ICCS Area 1

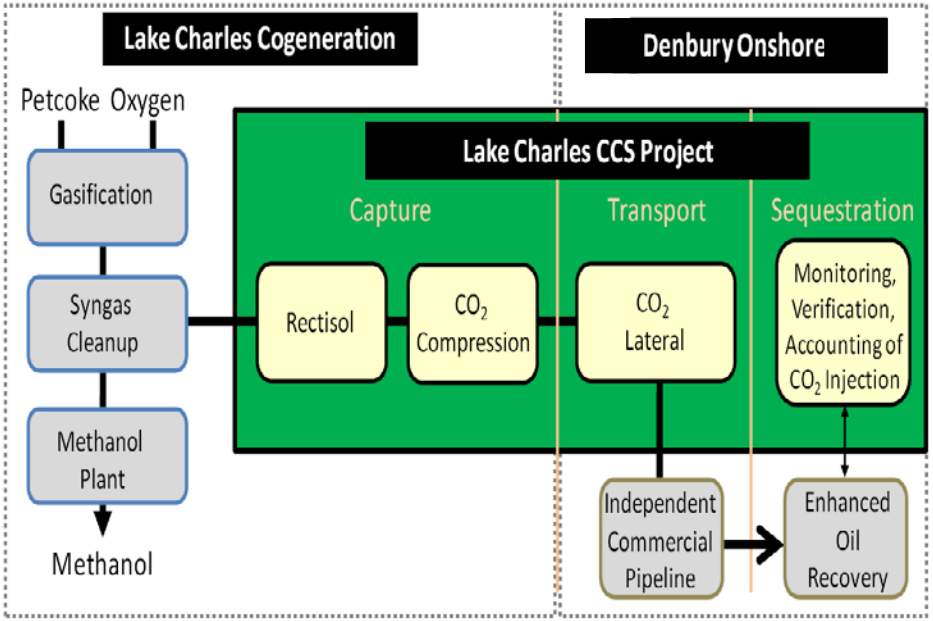
Steam Methane Reforming with CO_2 Capture

- **Port Arthur, Texas (Hydrogen plant located in Valero Refinery)**
- **90% CO_2 capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding >1,000,000 tons CO_2/year**
- **Installation of ~28 MWe cogeneration unit to supply ~110,000 lb/hr makeup steam to SMRs and operate VSA and Compression Equipment**
- **EOR in West Hastings oil field (Start: 2012)**
- **Total Project: $431 Million**
  DOE Share: $284 Million
- **Status:**
  - **FEED completed**
  - **Commercial Agreements in place**
  - **NEPA EA in progress**

Leucadia Energy, LLC ICCS Area 1

Lake Charles CCS Project

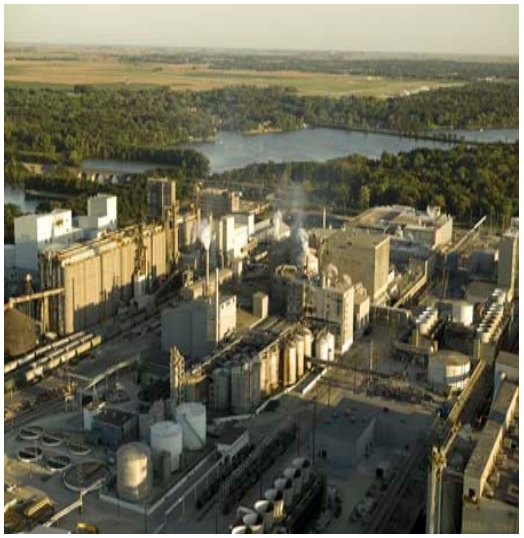
- Lake Charles, Louisiana
- GE Energy Gasification (5 gasifiers: 4 hot / 1 spare)
- 730 Million gallons / year methanol
- 90% CO_2 capture (Rectisol® process) 4,500,000 tons CO_2/year
- EOR in Texas at the West Hastings oil field (Start 2014)
- Total Project: $436 Million
  DOE Share: $261 Million
- Status
  - FEED in progress
  - NEPA in progress



Archer Daniels Midland Company ICCS Area 1

CO_2 Capture from Biofuel Plant

- **Decatur, Illinois**
- **Up to 90% CO_2 capture – dehydration (via tri-ethylene glycol) and compression (1,000,000 tons CO_2/year)**
- **CO_2 is a by-product in the production of fuel grade ethanol via anaerobic fermentation**
- **Sequestration in Mt. Simon Sandstone saline reservoir (Start: July 2013)**
- **Total Project: $208 Million**
  DOE Share: $141 Million
- **Status**
  - **NEPA completed**
  - **Design in progress**
  - **Site preparation in progress**



Unique features:

- **2 injection wells ~1 mile apart**
- **Large storage potential**

ADM ICCS Team Member Roles

- The project team members include ADM, Illinois State Geological Survey, Schlumberger Carbon Services, and Richland Community College.
- ADM: Overall project management; host site for capture and storage; design, construction, and operation of compression and dehydration facilities and substation
- ISGS: Site characterization, MVA (shallow), outreach and communication
- Schlumberger Carbon Services: Site characterization, drilling and injection operations, MVA (deep)
- Richland Community College: Sequestration training and monitoring facilities, outreach and communication

ADM ICCS Scope and Schedule

- **Scope of the project includes design, construction, and demonstration of CO_2 capture, CO_2 sequestration, and monitoring, verification, and accounting (MVA) of stored CO_2.**

- **Schedule:**
  - **70 months: 11/16/2009-9/30/2015;**
  - **Phase 1: 11/16/2009-8/15/2010;**
  - **Phase 2:**
  - **2a. Design: 8/16/2010;**
    2b. Construction:7/1/2011;
    2c. Operation: 7/1/2013-9/30/2015

ADM ICCS Monitoring, Verification, and Accounting (MVA)

- **MVA is an important part of the CCS projects to make geologic sequestration a safe, effective, and acceptable method for GHG control.**
- **Monitoring: CO_2 injection activities and rates, measuring soil gas, groundwater, and atmospheric CO_2 concentrations, CO_2 plume profiles in subsurface, reservoir pressure data, etc. Techniques include: 2D and 3D seismic surveys, verification and geophone wells, etc.**
- **Verification and Accounting are performed to ensure that the injected CO_2 is safely and permanently stored in the deep subsurface region.**

Concluding Remarks

- **DOE is pursuing a diversified set of carbon capture and sequestration technologies to address the needs of both coal-fired power plants and the industry. These major projects are at different stages of development. Some large-scale demonstrations are scheduled to begin as early as 2013.**

- **Best practice manuals are available at NETL website**
  - **Geologic Storage Formation Classifications**
  - **Site Screening, Selection, and Initial Characterization for Storage of CO_2**
  - **Monitoring, Verification, and Accounting of CO_2 Stored in Deep Geologic Formations**
  - **Public Outreach and Education for Carbon Storage Projects**
  - **Risk Analysis and Simulation for Geologic Storage of CO_2**

For Additional Information

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www.fe.doe.gov

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