Office of Clean Coal and Carbon Management

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U. S. Department of Energy

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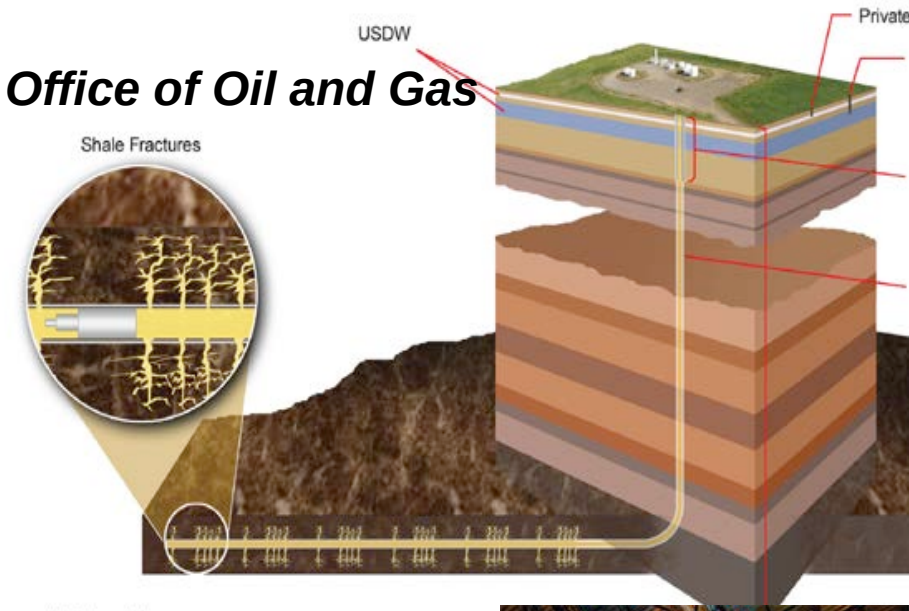
U.S. DEPARTMENT OF ENERGY
Fossil Energy

Office of Fossil Energy



National Energy Technology Laboratory

OFFICE OF FOSSIL ENERGY

Clean Coal & Carbon Management

VISION

A secure, reliable, and affordable energy future with the environmentally sound use of coal and all fossil fuels

MISSION

Support the research, development, and demonstration of advanced technologies to ensure the availability of clean, affordable energy from coal and fossil fuel resources

GOALS

1. Demonstrate significantly lower-cost CO_2 capture technologies to enable widespread deployment of near-zero emission fossil-based technologies
2. Acceptance by industry, financial institutions, regulators, and the public that CO_2 can be safely injected, monitored, and permanently stored in a variety of geologic formations
3. Conduct high-risk, transformational research and development on coal fossil fuel technologies
4. Drive international collaboration to ensure widespread acceptance and deployment of CCS and advanced coal technologies
5. Provide data and expertise to support policy, legislation, and regulation impacting fossil fuel research

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David Mohler
Deputy Assistant Secretary

Previously:

- Senior Vice President and Chief Technology Officer, Duke Energy
- Vice President of Strategic Planning, Cinergy

M.A., Xavier University of Cincinatti

M.S., University of Pennsylvania

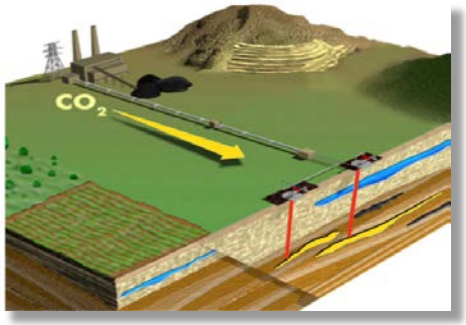
B.A., Indiana University

B.S., University of the State of New York at Albany

CO_2 Capture

Cost effective capture for new and existing plants

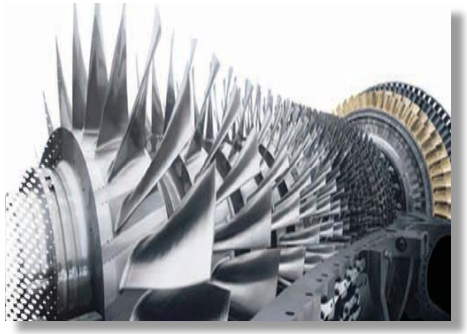
Major Goals: 2nd generation pilot tests (10 to 20 MW) by 2020. Transformational technology field tests by 2025



CO_2 Storage

Safe, permanent storage of CO2 from power and industry

Major Goals: technologies and tools available to measure and account for 99% of injected CO_2. CCS best practices and protocols completed by 2020.



Advanced Energy Systems

Gasification, Advanced turbines, Advanced combustion, CBTL, and fuel cells

Major Goals:

2025: 20-30% reduction in combined cycle capital cost (2nd gen)

2025: Advanced combustion ready for pilot scale operation (transformational)

Crosscutting Research

Crosscutting technology development program

Major Goals:

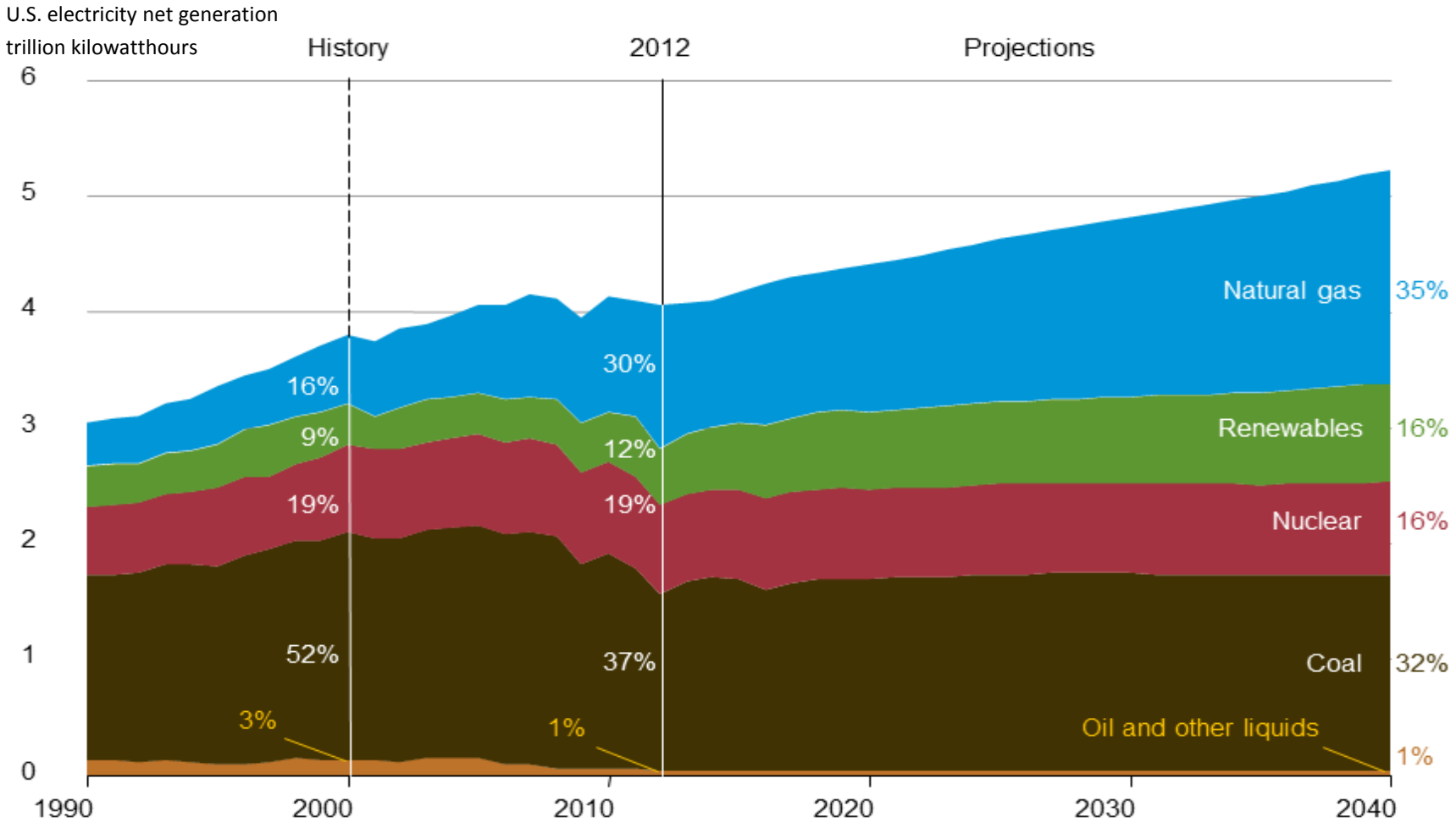
2016: advance 2nd gen materials, sensors, modeling technologies to applied programs

2020: develop distributed communication sensor networks (transformational tech)

- Rebalance the value equation for CO_2
  - R&D portfolio
  - 7 major demonstrations
- Quantify/demonstrate/document the viability of long term geologic storage of CO_2, including via enhanced oil recovery (EOR)
  - 7 regional partnerships
- Design/implement international collaborations to increase cooperation on carbon capture and sequestration (CCS) technologies
  - Promote bilateral partnerships for R&D collaboration with an emphasis on large scale projects
    - **Key partners:** China, Japan, UAE, Norway, UK, Canada, others…
  - Provide leadership in multilateral forums to develop CCS policy, leverage R&D platforms, and enhance information sharing/exchange of best practices (i.e., test center networks)
    - **Key partners:** CSLF, IEA, GCCSI, others…
- Innovate new power systems to increase efficiency

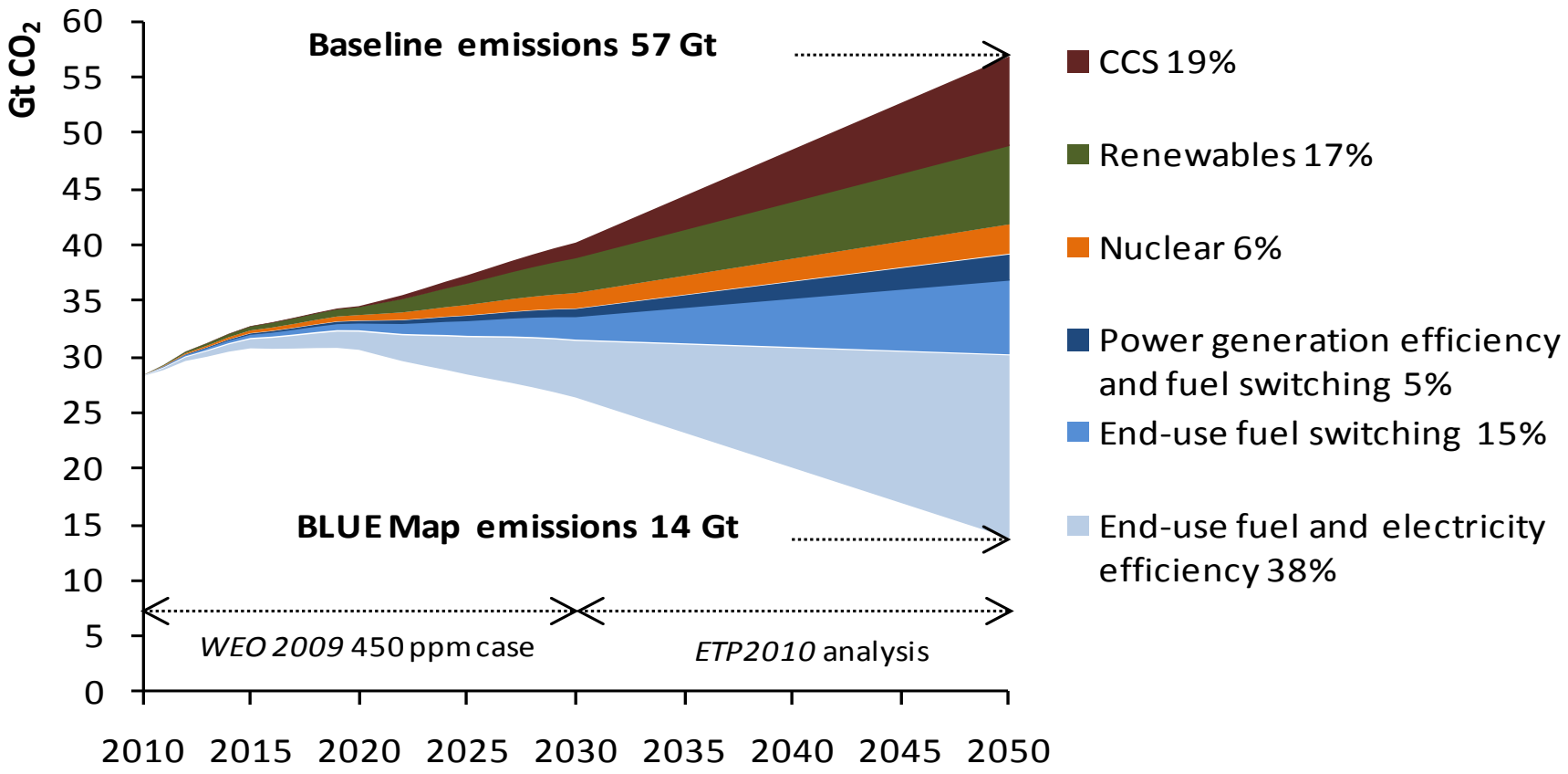
Why Coal?

Over time the electricity mix shifts toward natural gas and renewables, but coal remains the largest fuel source



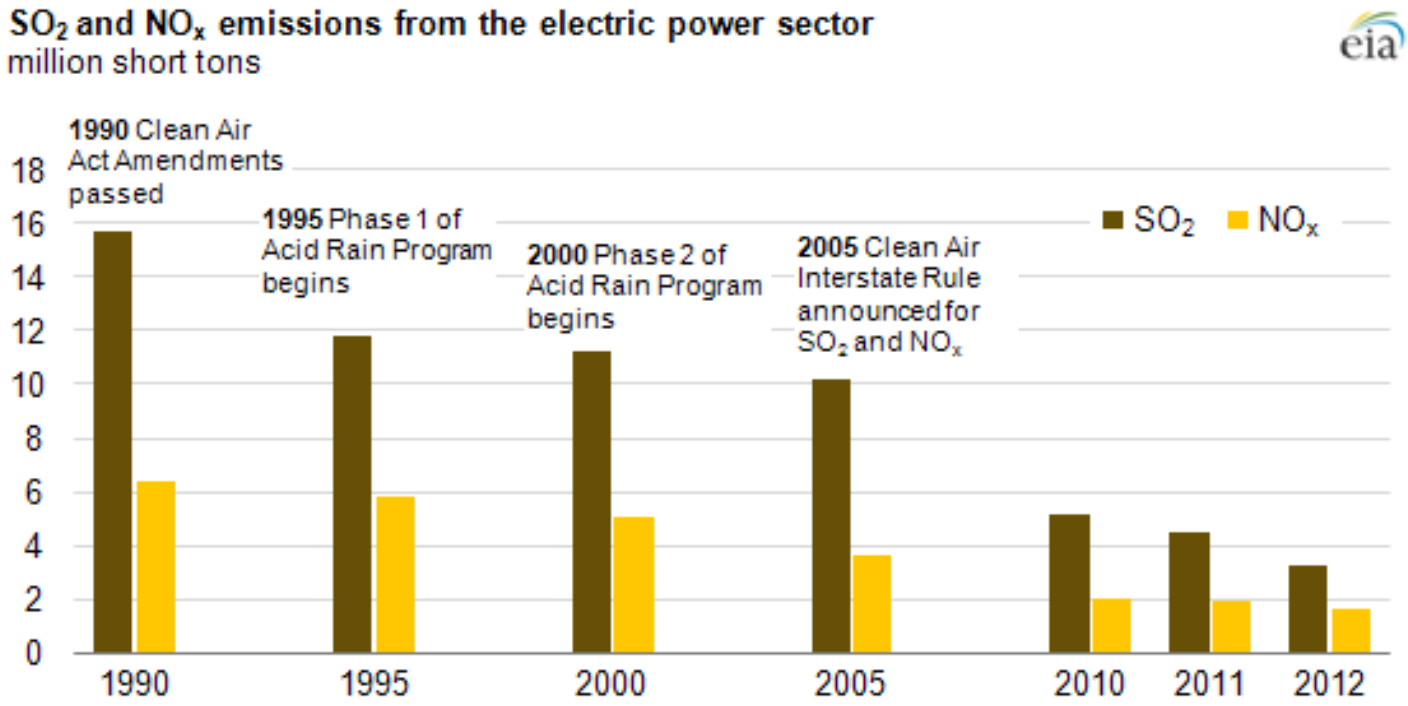
Source: EIA, Annual Energy Outlook 2014 Early Release

Advanced CCS Technologies are Critical to Reducing Global CO_2 Emissions



Clean Air Act of 1963 (extended in 1970, amended in 1977 and 1990)

- EPA to develop and enforce regulations to protect the public from airborne contaminants known to be hazardous to human health
- Early regulations focused on pollutants such as SO2, NOx, Mercury, and PMs from coal plants
- Newly proposed regulations 111(b) and 111(d) address carbon dioxide pollution

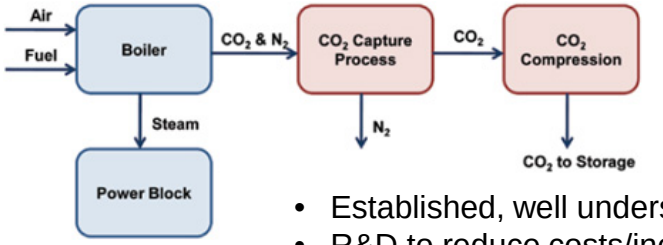


There are three broad categories of CO_2 capture technologies that can be applied to power plants

Post-Combustion Capture

Primarily applicable to conventional coal- or gas-fired power plants. In a typical coal plant, fuel is burned with air in a boiler to produce steam.

CO_2 is separated **after the fuel is combusted** using **sorbents, solvents or membrane systems**.

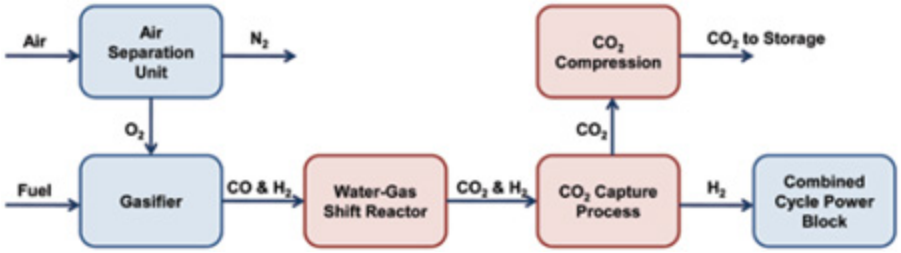


- Established, well understood technology
- R&D to reduce costs/increase efficiency
- Suitable for retrofit of existing plants

Pre-Combustion Capture

Primarily applicable to gasification plants, where solid fuel (coal, biomass, or coal/biomass mixture) is converted into gaseous components.

CO_2 is separated **prior to combustion**. Also decades old technology base applied commercially world-wide



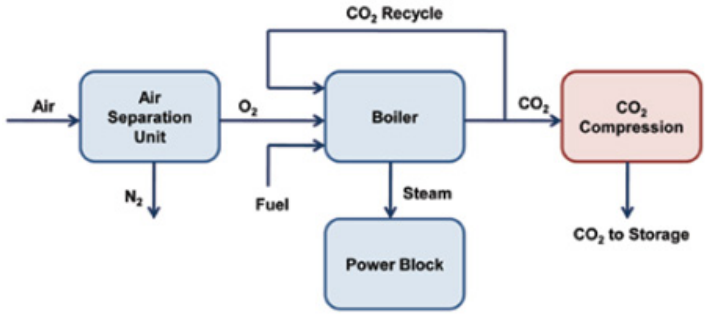
- Offers greater efficiency
- R&D/demonstrations address integration & cost challenges

Oxy-Combustion

Coal is combusted with relatively pure oxygen diluted with recycled CO_2 or CO_2/steam mixtures. Under these conditions, **the primary products of combustion is water and a highly concentrated CO_2 stream.** The CO_2 is separated from water vapor by condensing the water through cooling and compression

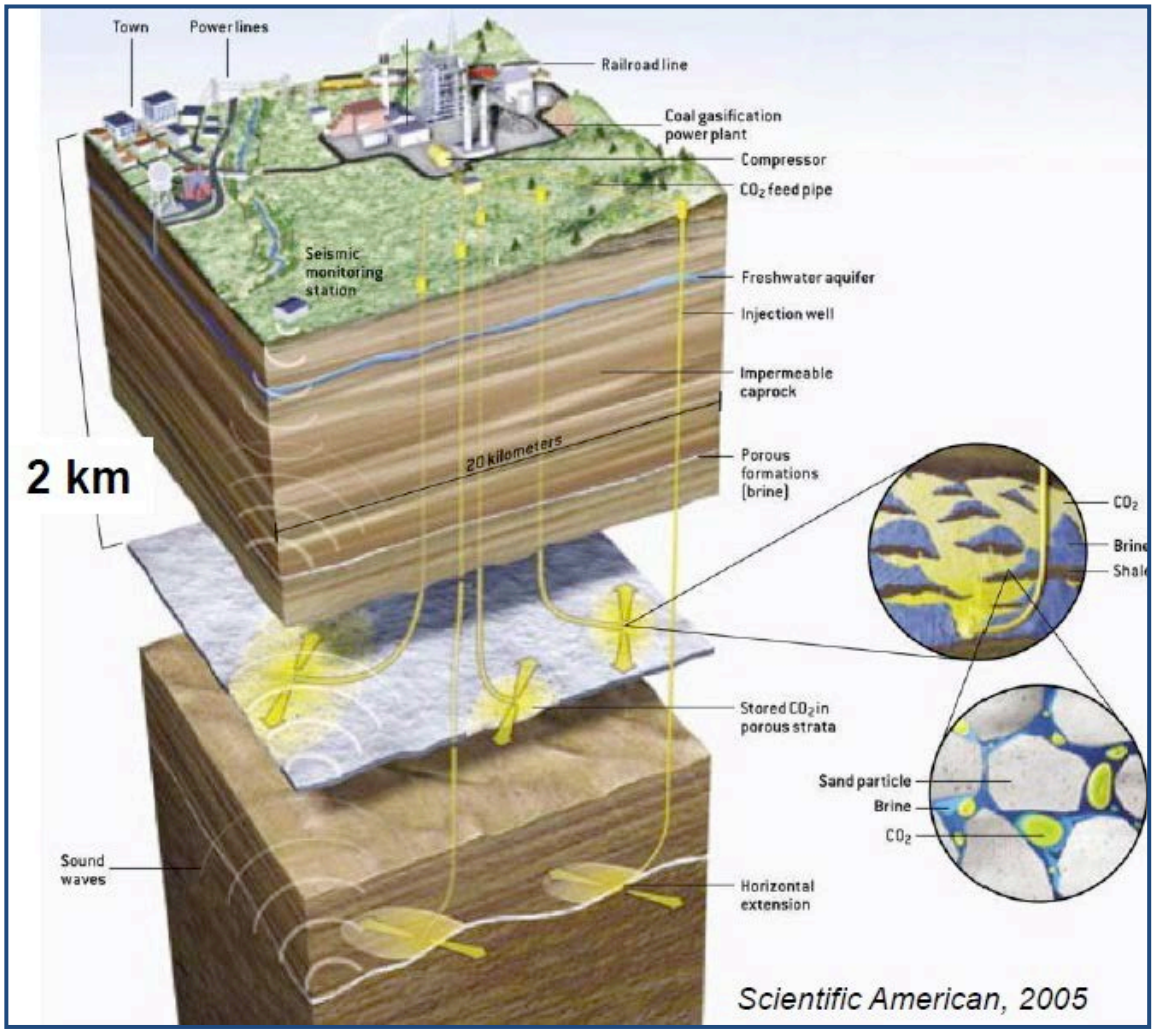
Suitable for new plants and for retrofits

Chemical Looping is a variant of oxy-combustion



- Emerging solution that may offer advantages over conventional pre-post combustion designs

CO_2 is captured and concentrated from large sources, then injected deep underground



Capture: Power plants and industrial sources

- Pre-combustion
- Post-combustion
- Oxyfired combustion
- Chemical looping

Storage: > 1km depth

- Porous & permeable units
- Large capacity
- Good seals and cap rock

Two main targets

- Saline formations (~2200 Gtons capacity in N. Am.)
- Enhanced oil recovery (~100 B bbls addl. recovery)

FE manages 8 major demonstration projects to advance capture technologies

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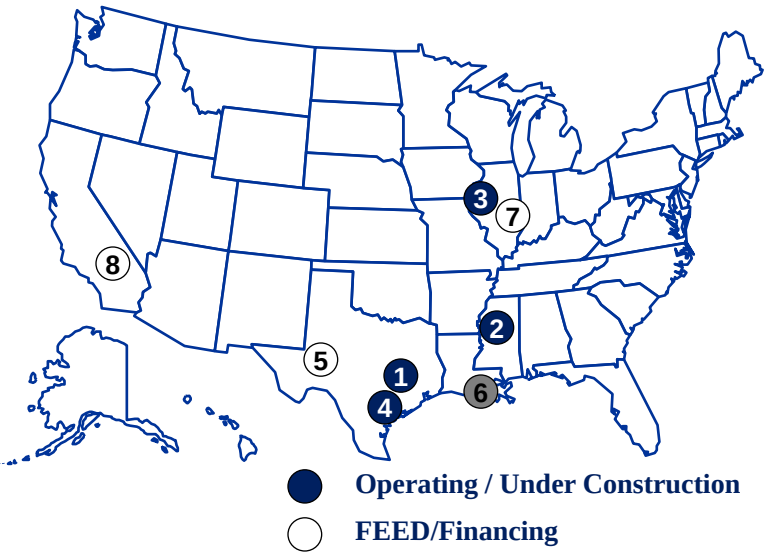
Major CCUS Demonstrations



	Partnership	Project	Status
1	Air Products	Steam Methane Reformer Hydrogen Production. EOR utilization ~925,000 MT/year	Operations
2	Southern Company Services (Kemper)	Integrated Gasification Combined Cycle (IGCC). EOR utilization ~3,000,000 MT/year	Under Construction
3	Archer Daniels Midland	Ethanol Fermentation CO2. Saline storage ~900,000 MT/year	Under Construction
4	NRG Energy (Petra Nova) WA Parish	Retrofit Pulverized Coal Plant. EOR utilization ~1,400,000 MT/year	Under Construction
5	Summit Texas Clean Energy Project	Integrated Gasification Combined Cycle Polygeneration. EOR utilization ~2,200,000 MT/year	Financing
6	Leucadia Energy, LLC	Methanol from Petcoke Gasification. EOR utilization ~4,500,000 MT/year	Front End Engineering & Design
7	FutureGen 2.0	Oxycombustion Pulverized Coal Boiler Retrofit. Saline storage ~1,000,000 MT/year	Front End Engineering & Design
8	Hydrogen Energy California (HECA)	Integrated Gasification Combined Cycle Polygeneration. EOR utilization ~2,570,000 MT/year	Front End Engineering & Design

- Portfolio represents both EOR and storage in saline aquifers
- Portfolio includes industrial and power capture
- Portfolio includes pre-, post-, and oxy-combustion capture

Commercial scale CCS Demonstrations are major industrial projects

Kemper County Energy Facility

Collaboration with Southern Company

- 582 MW plant
- $ 4.7 billion total project cost
    - DOE share: $270 million
- Plant construction: 95% complete; more than 3,500 construction workers on site
- Approximately 67% carbon capture (3,000,000 tons of CO_2 per year for EOR)

CO_2 Capture Demonstrations : Program highlights

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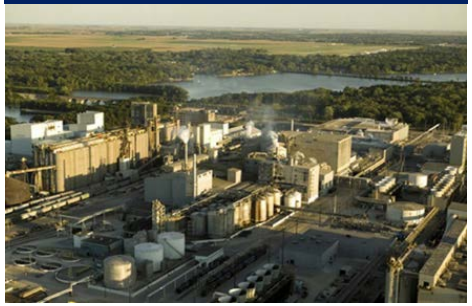
Air Products Industrial Capture to EOR

Archer Daniels Midland Ethanol CO_2 Capture



Petra Nova Retrofit

Air Products Industrial Capture to EOR

Port Arthur, TX (Hydrogen plant at Valero Refinery)

90%+ CO_2 capture (Vacuum Swing Adsorption) from 2 steam methane reformers yielding ~925,000 tonnes CO_2/year

CO_2 delivered for EOR in West Hastings oil field

Total Project: $431 million. DOE share: $284 million

Project executed on time and under budget. +700k hours with no lost time incidents.

Archer Daniels Midland, Ethanol Capture and Saline Storage

Decatur, Illinois

90%+ capture from ethanol fermentation, compression, and injection into saline formation

Design: ~1,000,000 tonnes CO_2 / year; injection directly under project site (100% Saline)

Project nearly completed; Second Class VI permit issued by EPA (Region 5)

Operations: Early-2015

Total Project: $207 million. DOE share: $66 million

Petra Nova (NRG) Advanced Post Combustion Capture Retrofit

Thompsons, TX

240 MWe slipstream at NRG's W.A. Parish power plant (scaled up from original 60 Mwe)

90% CO_2 capture ~1,400,000 tonnes CO_2/year (2.2 MT to EOR, 0.5 MT to urea)

EOR: Hilcorp West Ranch Oilfield

Total Project: $1 billion. DOE share: $167million

Achieved financial close and began construction July 15, 2014

CCS Best Practices Manuals

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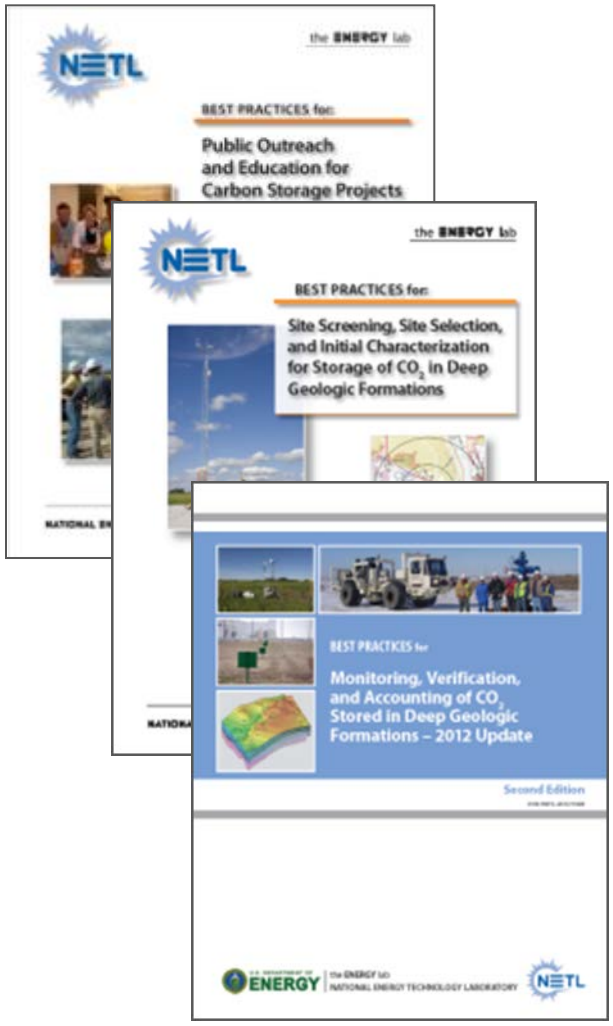
Critical Requirement For Significant Wide Scale Deployment - Capturing Lessons Learned



Best Practices Manual	Version 1 (Phase II)	Version 2 (Phase III)	Final Guidelines (Post Injection)
Monitoring, Verification and Accounting	2009/2012	2016	2020
Public Outreach and Education	2009	2016	2020
Site Characterization	2010	2016	2020
Geologic Storage Formation Classification	2010	2016	2020
**Simulation and Risk Assessment	2010	2016	2020
**Carbon Storage Systems and Well Management Activities	2011	2016	2020
Terrestrial	2010	**2016 – Post MVA Phase III**	

CO_2 Storage Demonstrations
FE manages 7 regional partnerships to conduct CO2 injection projects

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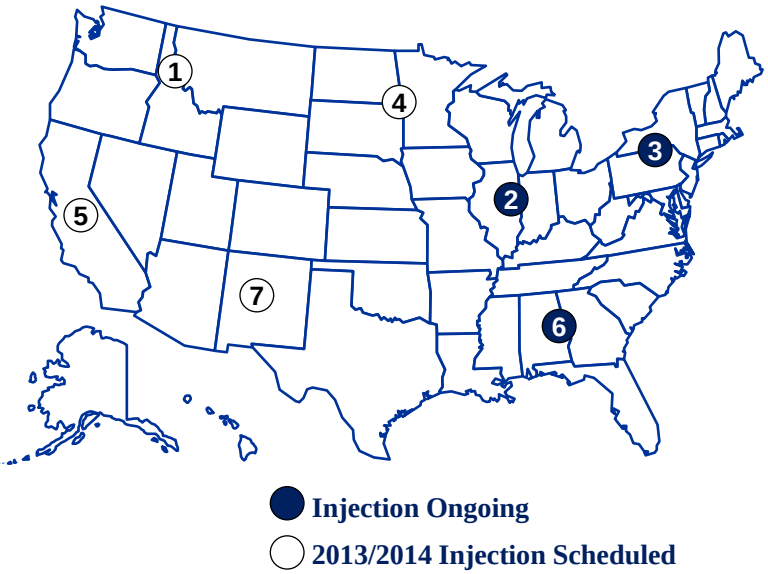
Regional Carbon Sequestration Partnerships



- Geology: Projects represent six of eleven identified depositional environments in the United States.
- Storage methodology: Projects include EOR and saline aquifer storage
- Preceded by 20 small-scale projects that cumulatively injected over 1 million tonnes

	Partnership	Project	Status
1	Big Sky Carbon Sequestration Partnership	Saline storage of naturally occurring CO_2 (1 million tonnes over 4 years)	Site operations; Injection 2014
2	Midwest Geological Sequestration Consortium	Saline storage of CO_2 from ADM biofuel production (1 million tonnes over 3 years)	Injection began Nov. 2011
3	Midwest Regional Carbon Sequestration Partnership	EOR using CO_2 from gas processing plant (1 million tonnes over 4 years)	Injection began Feb. 2013
4	Plains CO_2 Reduction Partnership	1) Project 1: EOR using CO_2 from ConocoPhillips Gas Plant (1 million tonnes over 2 years) 2) Project 2: Saline storage of CO_2 from Spectra Energy gas processing plant (1.3 million tonnes over 2 years)	1) Injection June 2013 2) Site operations; injection 2015
5	West Coast Regional Carbon Sequestration Partnership	Regional Characterization	No large-scale injection
6	Southeast Regional Carbon Sequestration Partnership	1) Project 1: Saline leg of EOR; storage natural CO_2 (Over 3.6 million tonnes by Sept. 2014) 2) Project 2: Saline storage of amine captured CO_2 from coal-fired generation (250,000 tonnes over 2 years)	1) Injection began 2009 2) Injection began Aug. 2012
7	Southwest Regional Partnership on Carbon Sequestration	EOR storage of CO_2 from fertilizer and ethanol plants (1 million tonnes over 5 years)	Site operations; injection late 2013