Office of Clean Coal and Carbon Management

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Office of Fossil Energy

Office of Clean Coal and Carbon Management

Office of Oil and Gas

Strategic Petroleum Reserves

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- Senior Vice President and Chief Technology Officer, Duke Energy
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Office of Clean Coal and Carbon Management

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<tr>
<th>CO₂ Capture</th>
<th>CO₂ Storage</th>
<th>Advanced Energy Systems</th>
<th>Crosscutting Research</th>
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<tr>
<td>Cost effective capture for new and existing plants</td>
<td>Safe, permanent storage of CO₂ from power and industry</td>
<td>Gasification, Advanced turbines, Advanced combustion, CBTL, and fuel cells</td>
<td>Crosscutting technology development program</td>
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</table>
Rebalance the value equation for CO₂
  • R&D portfolio
  • 7 major demonstrations

Quantify/demonstrate/document the viability of long term geologic storage of CO₂, 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
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

Baseline emissions 57 Gt

BLUE Map emissions 14 Gt

- CCS 19%
- Renewables 17%
- Nuclear 6%
- Power generation efficiency and fuel switching 5%
- End-use fuel switching 15%
- End-use fuel and electricity efficiency 38%

WEO 2009 450 ppm case
ETP2010 analysis

- 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.

**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.

**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
CO₂ 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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<tr>
<th>Partnership</th>
<th>Project</th>
<th>Status</th>
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<tr>
<td>1 Air Products</td>
<td>Steam Methane Reformer Hydrogen Production. EOR utilization ~925,000 MT/year</td>
<td>Operations</td>
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<tr>
<td>2 Southern Company Services (Kemper)</td>
<td>Integrated Gasification Combined Cycle (IGCC). EOR utilization ~3,000,000 MT/year</td>
<td>Under Construction</td>
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<tr>
<td>3 Archer Daniels Midland</td>
<td>Ethanol Fermentation CO2. Saline storage ~900,000 MT/year</td>
<td>Under Construction</td>
</tr>
<tr>
<td>4 NRG Energy (Petra Nova)</td>
<td>retrofit Pulverized Coal Plant. EOR utilization ~1,400,000 MT/year</td>
<td>Under Construction</td>
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<tr>
<td>5 Summit Texas Clean Energy Project</td>
<td>Integrated Gasification Combined Cycle Polygeneration. EOR utilization ~2,200,000 MT/year</td>
<td>Financing</td>
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<tr>
<td>6 Leucadia Energy, LLC</td>
<td>Methanol from Pet coke Gasification. EOR utilization ~4,500,000 MT/year</td>
<td>Front End Engineering &amp; Design</td>
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<tr>
<td>7 FutureGen 2.0</td>
<td>Oxycombustion Pulverized Coal Boiler Retrofit. Saline storage ~1,000,000 MT/year</td>
<td>Front End Engineering &amp; Design</td>
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<tr>
<td>8 Hydrogen Energy California (HECA)</td>
<td>Integrated Gasification Combined Cycle Polygeneration. EOR utilization ~2,570,000 MT/year</td>
<td>Front End Engineering &amp; Design</td>
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- 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 CO₂ per year for EOR)
CO₂ Capture Demonstrations: Program highlights

**Air Products Industrial Capture to EOR**
Port Arthur, TX (Hydrogen plant at Valero Refinery)
90%+ CO₂ capture (Vacuum Swing Adsorption) from 2 steam methane reformers yielding ~925,000 tonnes CO₂/year
CO₂ 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 CO₂/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% CO₂ capture ~1,400,000 tonnes CO₂/year (2.2 MT to EOR, 0.5 MT to urea)
EOR: Hilcorp West Ranch Oilfield
Total Project: $1 billion. DOE share: $167 million
Achieved financial close and began construction July 15, 2014
## CCS Best Practices Manuals

### Critical Requirement For Significant Wide Scale Deployment - Capturing Lessons Learned

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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 CO₂ (1 million tonnes over 4 years) | Site operations; Injection 2014
2 | Midwest Geological Sequestration Consortium | Saline storage of CO₂ from ADM biofuel production (1 million tonnes over 3 years) | Injection began Nov. 2011
3 | Midwest Regional Carbon Sequestration Partnership | EOR using CO₂ from gas processing plant (1 million tonnes over 4 years) | Injection began Feb. 2013
4 | Plains CO₂ Reduction Partnership | 1) Project 1: EOR using CO₂ from ConocoPhillips Gas Plant (1 million tonnes over 2 years) 2) Project 2: Saline storage of CO₂ 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 CO₂ (Over 3.6 million tonnes by Sept. 2014) 2) Project 2: Saline storage of amine captured CO₂ 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 CO₂ from fertilizer and ethanol plants (1 million tonnes over 5 years) | Site operations; injection late 2013