Demonstration Projects: Taking It Commercial

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**Critical R&D Challenges to Near-Zero Emissions from Coal**

**Near-Term Plants**
- Pulverized Coal
  - Power generation
  - Improve efficiencies
  - Minimize criteria pollutants
  - Minimize water usage
  - Minimize greenhouse gases

**Future Plants**
- Advanced Coal
  - Power and multiple products
  - Improve reliability
  - Maximize efficiencies
  - Near-zero criteria pollutants
  - Near-zero water usage
  - Near-zero greenhouse gases

**Technology Bridge to Near-Zero Emissions**

- **2005 – 2020**
- **2020 – 2050**
Cost Share Ensures Commercial Relevance

DOE Research Programs

0 % Cost Share | 0 to 20 % Cost Share | 20 to 50 % Cost Share | >= 50 % Cost Share

Office of Science Research

Fossil Energy Advanced Research

Fossil Energy Core Programs

Demonstrations

Basic Research
Applied Research
Bridges basic research & technology development programs

Process & Engineering Development
Pilot plants, Proof-of concept (POC) units, Mini-demonstrations

Demonstration & Commercialization

Industry Participation & Cost Sharing Increases

U.S. Global Competitiveness
Emissions Control & Efficiency Improvements

Notable Program Successes

Advanced Pollution Controls
- Installed on 75% of U.S. coal plants
- 1/2 to 1/10 cost of older systems

HAPS & Hg Data
- Quantified Hazardous Air Pollutant (HAPs) Levels
- Basis for Mercury (Hg) Regulations

Advanced Coal Power Systems
- First large (265 MW) Circulating Fluidized Bed Combustion (CFBC) power plant
- Two “super-clean” Integrated Gasification Combined Cycle (IGCC) power plants

Notable Projects:
- Jacksonville CFBC
- Wabash IGCC
- Tampa IGCC

Flue Gas Desulfurization (FGD) Scrubbers
Low-NOx Burners
## Return on Investment from Fossil Energy RD&D

### FE Research — The Return on Investment

<table>
<thead>
<tr>
<th>Benefits/Program</th>
<th>Description</th>
<th>Start Year</th>
<th>End Year</th>
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<tbody>
<tr>
<td>$111 billion in benefits(^1)</td>
<td>37 million add’l tons of avoided SO(_2), 16 million add’l tons of avoided NO(_x)(^1)</td>
<td>2000–2020</td>
<td>2000–2020</td>
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<tr>
<td>$13 return for every $1 invested(^3)</td>
<td>1.2 million jobs created(^1)</td>
<td>2000–2020</td>
<td>2000–2020</td>
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<tr>
<td>12-fold increase in shale gas production(^2)</td>
<td>10-fold increase in EOR using CO(_2) injection(^3)</td>
<td>2000–2011</td>
<td>1985–2010</td>
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<td>50–70% cost reduction in mercury control at coal-fired power plants(^4)</td>
<td></td>
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<td>2000–2008</td>
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Major CCS Demonstration Projects

**Project Locations & Cost Share**

**FutureGen 2.0**
- Large-scale Testing of Oxy-Combustion w/ CO₂ Capture and Sequestration in Saline Formation
- Project: ~$1.65B – Total; ~$1.0B – DOE
- SALINE – 1 MM TPY 2017 start

**Summit TX Clean Energy**
- Commercial Demo of Advanced IGCC w/ Full Carbon Capture
- ~$1.7B – Total, $450M – DOE
- EOR – ~2.2 MMTPY 2017 start

**HECA**
- Commercial Demo of Advanced IGCC w/ Full Carbon Capture
- ~$4B – Total, $408M – DOE
- EOR – ~2.6 MM TPY 2019 start

**NRG**
- W.A. Parish Generating Station Post Combustion CO₂ Capture
- $775 M – Total
- $167M – DOE
- EOR – ~1.4 MM TPY 2016 start

**Air Products and Chemicals, Inc.**
- CO₂ Capture from Steam Methane Reformers
- EOR in Eastern TX Oilfields
- $431M – Total, $284M – DOE
- EOR – ~0.93 MM TPY 2012 start

**Southern Company**
- Kemper County IGCC Project Transport Gasifier w/ Carbon Capture
- ~$2.01B – Total, $270M – DOE
- EOR – ~3.0 MM TPY 2014 start

**Archer Daniels Midland**
- CO₂ Capture from Ethanol Plant
- CO₂ Stored in Saline Reservoir
- $208M – Total, $141M – DOE
- SALINE – ~0.9 MM TPY 2014 start

**Leucadia Energy**
- CO₂ Capture from Methanol Plant
- EOR in Eastern TX Oilfields
- $436M - Total, $261M – DOE
- EOR – ~4.5 MM TPY 2017 start
Southern Company Services, Inc. CCPI-2

**Advanced IGCC with CO₂ Capture**

- Kemper County, MS
- 582 MWe (net); 58 MWe duct firing; 2 TRIG™ gasifiers, 2 Siemens combustion turbines, 1 Toshiba steam turbine
- Fuel: Mississippi lignite
- ~67-69% CO₂ capture (Selexol® process); 3,000,000 tons CO₂/year
- EOR; Denbury Onshore LLC, Treetop Midstream Services LLC
- Total DOE Project: $2.01 Billion; DOE Share: $270 Million (13%)
- Total estimated plant cost: ~$4.1 Billion

**Key Dates**
- Project Awarded: Jan 30, 2006
- Project moved to MS: Dec 5, 2008
- NEPA Record of Decision: Aug 19, 2010
- Initiate excavation work: Sept 27, 2010
- Operations: May 2014

**Status**
- Plant construction >73% complete; ~6,000 construction personnel on site
- CO₂ off-take agreements signed
- Lignite mine under development
- Subsystems (water treatment, cooling towers) to begin pre-commissioning
- Combustion turbine startup: Aug/Sept 2013
- Gasifier heat-up: Dec 2013
Air Products and Chemicals, Inc. ICCS Area 1

Steam Methane Reforming with CO₂ Capture

- Port Arthur, TX (Hydrogen plant at Valero Refinery)
- 90%+ CO₂ capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding ~925,000 tonnes CO₂/year
- ~30 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and compression equipment
- CO₂ to Denbury pipeline for EOR in Texas at West Hastings oilfield
- Total Project: $431 Million
  DOE Share: $284 Million (66%)

Key Dates
- Phase 2 Awarded: June 15, 2010
- FEED complete: Nov 2010
- Permit By Rule (PBR) and Standard Air Permits issued: May 2011
- NEPA FONSI: July 2011
- Construction start: Aug 2011
- Operation start: Dec 2012

Status
- PA-1 initiated operation: March 3, 2013
- PA-2 initiated operation: Dec 16, 2012
- Total CO₂ delivered (8/21/13): 445,139 tons
- Full project capacity achieved: April 2013
Air Products and Chemicals, Inc: Port Arthur 2
Archer Daniels Midland Company ICCS Area 1

**CO₂ Capture from Biofuel Plant**

- Decatur, IL
- CO₂ is a by-product (>99% purity) from production of fuel grade ethanol via anaerobic fermentation
- Up to 90% CO₂ capture; dehydration (via tri-ethylene glycol, TEG) and compression; ~900,000 tons CO₂ /year
- Sequestration in Mt. Simon sandstone formation
- Total Project: $208 Million
  DOE Share: $141 Million (68%)

**Key Dates**
- Phase 2 Awarded: Jun 15, 2010
- FEED Complete: Apr 2011
- NEPA FONSI: Apr 2011
- Construction start: May 2011
- UIC Class VI Injection Well Permit: Jan 2014;
- Sequestration start: July 2014

**Status**
- Construction ~50% complete
- Substation construction in progress
- Two monitoring wells drilled: Nov 2012
- Commissioning compression & dehydration: July 2013
National Sequestration Education Center
Richland Community College

• Public outreach, training, & education initiative to engage local communities to understand CCUS & related environmental benefits

• National Sequestration Education Center (NSEC) - a new education and training facility http://nsec.richland.edu/
  – 15,000 ft² center - classrooms, training, and laboratory facilities
  – Opened September 2012
  – Associate degree program with carbon sequestration specialty
  – Operates Sequestration Technology Educational Learning Array in the Visitor’s Center – Interactive program to learn CCUS
Back-Up Slides

*on 5 Remaining Major Demonstration Projects*

Clean Coal Power Initiative (CCPI)

- NRG
- Summit
- HECA

FutureGen 2.0

Industrial Carbon Capture & Sequestration (ICCS)

- Leucadia-Lake Charles
W.A. Parish NRG Energy CCPI-3
Advanced Post Combustion CO₂ Capture

- Thompsons, TX (near Houston)
- 240 MWe slipstream at NRG Energy’s W.A. Parish power plant (project scale up from original 60 MWe to improve economic)
- Fuel: PRB sub-bituminous coal
- 90% CO₂ capture (KM CDR Process®) 1,400,000 tonnes CO₂/year
- EOR: Hilcorp West Ranch oil field
- Total DOE Project: $775 Million (est.)
  DOE Share: $167 Million (21.5%)

Key Dates
- Project Awarded: May 2010
- Air Permit: Dec 2012
- NEPA Record of Decision: May 2013
- Financial Close: Feb 2014
- Construction: Feb 2014
- Operation: May 2016

Status
- EOR Host Site acquired: Oct 2011
- 240 MWe FEED completed: Feb 21, 2012
- MHI initiated detailed design: Dec 2012
- NRG-Petra Nova signed engagement letter with a debt financing provider: Dec 2012
Scaling up the Project - EOR

- NRG & Hilcorp concluded that the proposed 60MW sized project’s 20,000 MCF/day CO₂ production rate was too small to induce meaningful oil production.

  120 MWe Model Results (40,000 MCF/Day)

  215 MWe Model Results (80,000 MCF/Day)

- NRG & Hilcorp determined that the best-sized application to support the CO₂ miscible flooding requirements of the candidate oil fields is 200-250MW.

Co-optimization of CO₂ production with enhanced oil recovery response.
WA Parish Site Overview

- Flue Gas Source
- General Duct Location
- CCS Process Area
- BOP: CT, Cooling Tower, etc.
Summit Texas Clean Energy, LLC CCPI-3

**Advanced IGCC-Polygen**

- Penwell, Ector County, TX
- 200 MW (net), 0.7 MMT/yr Urea; greenfield IGCC with Siemens gasification & power Block
  - SFG-500 gasifiers (2 x 50%)
  - High H₂ SGCC6-5000F combined cycle (1 x 1)
- Fuel: PRB sub bituminous coal
- 90% CO₂ capture – ~2,700,000 tons CO₂/year
  - 2.2 MM tonnes EOR; 0.5 MM to Urea production
  - 2-stage Water Gas Shift, Linde Rectisol® AGR
- EOR: Permian Basin oil fields
- Total DOE Project: $1.727 Billion
  - DOE Share: $450 Million (26%)
- Total Plant Cost ~$2.9 Billion

**Key Dates**

- Project Awarded: Jan 2010
- Air Permit; Dec 2010
- NEPA Record of Decision: Sep 2011
- Financial Close: Oct 2013
- Construction: 4th Q2013
- Operation: Nov 2017

**Status**

- Urea contract: Jan 2011
- CO₂ contract(s): Nov 2011
- Power off-take contract: Dec 2011
- Chexim signed for debt financing MOU: Sep 2012
- Sinopec signed EPC agreement: Dec 2012
Summit Texas Clean Energy, LLC

Plant Site

Northwest Border of Pennwell Site
(Facing East)

Kinder Morgan CO$_2$ Interconnect
Hydrogen Energy California

**Advanced IGCC-Polygen**

- Kern County, CA
- Up to 300 MWe (net) with load following; greenfield IGCC, 1.0 MT/yr Urea/UAN
  - MHI oxygen-blown gasifier (1 x 100%)
  - MHI G-class air cooled combustion turbine (1)
- Fuel: Sub-bituminous coal/petcoke
- 90% CO₂ capture – 3,020,000 tonnes CO₂/year
  - 2.57 MM tonnes EOR; 0.45 MM Urea production
  - 2-stage Water Gas Shift, Linde Rectisol ® AGR
- EOR: Elk Hills oil field
- Use of brackish water for power production; ZLD
- Total DOE Project: $4.028 Billion DOE - $408 Million (10%)
- Total Plant Cost: ~$5 Billion

**Key Dates**
- Project Awarded: Sep 2009
- New Owner, SCS Energy: Sep 2011
- Financial Close: Jun 2014
- Start of Construction: Jan 2015
- Start of Operation: Jul 2019

**Status**
- Power/Fertilizer/CO₂/EPC discussions in progress
- FEED completion: Apr 2013
- Draft PSA/EIS: Jun 2013
- Final Determination of Compliance (air permit): Jul 2013
FutureGen 2.0

Oxy-combustion with Geologic Storage

- Morgan County, IL (western IL)
- 168 MWe repowering of an existing steam turbine generator at Ameren’s Meredosia Energy Center
- Fuel: Illinois bituminous/PRB blend
- 90+% CO₂ capture (cryogenic separation)
  1,000,000 tons CO₂/year
- Geologic Storage, Mt. Simon Sandstone saline formation - ~30 miles east of power plant
- Total DOE Project: $1.78 Billion
  DOE Share: $1.05 Billion (59%)

Key Dates
- Project Awarded: October 2010
- NEPA Complete (Planned): Fall 2013
- Financial Close: Summer 2014
- Construction: Fall 2014
- Operation: Summer 2017

Status
- Storage site selected: Oct 2011
- Pre-FEED completed: Apr 2012
- Preliminary PPA approved by ICC: Dec 2012
- Power plant project novated to FGA: Jan 2013
- Phase II (NEPA, Permitting, and Design) authorized: Feb 2013
Leucadia Energy, LLC ICCS Area 1

*Petcoke Gasification to Methanol*

- Lake Charles, LA
- GE Energy Gasification
  (4 gasifiers: 3 hot/1 spare)
- 700 mmgal/yr methanol; 110 mmscfd H₂
- Fuel: Petcoke
- 89% CO₂ capture (Rectisol® process); 4,500,000 tonnes CO₂/year
- CO₂ to Denbury pipeline for EOR in Texas at West Hastings oil field
- Total Project: $436 Million
  DOE Share: $261 Million (60%)

**Key Dates**
- Phase 2 awarded: Jun 17, 2010
- Complete CCUS FEED: Jul 2011
- NEPA ROD: Oct 2013
- Financial close: Oct 2013 (est.)
- Construction: Oct 2013 (est.)
- Operation: Mar 2017 (est.)

**Status**
- Product off-take contracts finalized (BP, APCI)
- NEPA EIS in progress; Draft EIS public meetings - Apr 2013
- FEED in progress for gasification plant