Overview of DOE’s Office of Fossil Energy Priorities

2014 SSEB Committee on Clean Coal & Energy Technologies

Joseph Giove III
Director, Division of CCS Demonstrations
May 20, 2014
FE’s Coal RD&D Investment Strategy

**Approaches**
- Technology Development
- Commercial Readiness
- Market Penetration

**Programs**

**RESEARCH & DEVELOPMENT**
- Core Coal and Power Systems R&D
  - DOE – FE – NETL

**TECHNOLOGY DEMONSTRATION**
- FutureGen 2.0
- Clean Coal Power Initiative
- Industrial CCS
  - DOE – FE – NETL

**FINANCIAL INCENTIVES**
- Tax Credits
- Loan Guarantees
  - DOE – LGO – IRS
Key Priorities

Deliver the large CCS projects (both CCPI and ARRA) to maximum scientific and technical benefit

• This accelerated deployment of clean coal technology provides key decision makers the technical and economic information needed for investment, regulation, and policy

Support a diverse clean coal research program likely to bring to market large improvements in cost, efficiency, and performance

• This increases the pool of potentially viable technologies that can serve commercial and industrial needs and reduces the risk of technical failure for public investments

Ensure excellence in program design and execution

• This serves the taxpayers, technical community, and industrial communities well

Reduce cost of capture, reduce risk of storage
Pathway for Technology Commercialization

We need more 2nd generation pilots!
## Capture Program: Active Portfolio Distribution

**Supporting deployment of 2nd Generation Technologies**

<table>
<thead>
<tr>
<th>Program Area</th>
<th>Key Technology</th>
<th>Number of R&amp;D Projects</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>TRL 1</td>
<td>TRL 2</td>
</tr>
<tr>
<td><strong>Post-Combustion Capture</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvents</td>
<td>3</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Sorbents</td>
<td>3</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Membranes</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Hybrid/Novel</td>
<td>5</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Pre-Combustion Capture</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvents</td>
<td>2</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Sorbents</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Membranes</td>
<td>2</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Hybrid/Novel</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Compression</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td><strong>TRL Totals</strong></td>
<td></td>
<td>24</td>
<td>33</td>
</tr>
</tbody>
</table>

**Need for transformational technology ideas**

“Wave” of bench scale projects approaching graduation (1/2 of portfolio)

Up to 12 candidate ≤1MW pilots progressing toward large pilot-scale tests (10-50 MW)
## CCS & Power Systems Funding
### FY 2013 - 2015

<table>
<thead>
<tr>
<th>($ in thousands)</th>
<th>FY 2013 Current</th>
<th>FY 2014 Enacted</th>
<th>FY 2015 Congressional Request</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CCS demonstrations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural gas carbon capture and storage</td>
<td>0</td>
<td>0</td>
<td>25,000</td>
</tr>
<tr>
<td><strong>CCS AND POWER SYSTEMS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Carbon Capture</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-Combustion Capture Systems</td>
<td>51,336</td>
<td>80,000</td>
<td>65,000</td>
</tr>
<tr>
<td>Natural Gas CCS Prize</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pre-Combustion Capture Systems</td>
<td>12,389</td>
<td>12,000</td>
<td>12,000</td>
</tr>
<tr>
<td><strong>Total Carbon Capture</strong></td>
<td>63,725</td>
<td>92,000</td>
<td>77,000</td>
</tr>
<tr>
<td><strong>Carbon Storage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage Infrastructure (formerly Regional Carbon Sequestration Partnerships)</td>
<td>76,961</td>
<td>71,866</td>
<td>60,084</td>
</tr>
<tr>
<td>Geologic Storage</td>
<td>13,845</td>
<td>16,300</td>
<td>8,500</td>
</tr>
<tr>
<td>Monitoring, Verification, Accounting, and Assessment</td>
<td>6,229</td>
<td>10,000</td>
<td>4,500</td>
</tr>
<tr>
<td>Carbon Use and Reuse</td>
<td>719</td>
<td>800</td>
<td>0</td>
</tr>
<tr>
<td>Focus Area for Carbon Sequestration Science</td>
<td>8,991</td>
<td>9,800</td>
<td>7,000</td>
</tr>
<tr>
<td><strong>Total Carbon Storage</strong></td>
<td>106,745</td>
<td>108,766</td>
<td>80,084</td>
</tr>
<tr>
<td><strong>Advanced Energy Systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced Combustion Systems</td>
<td>14,790</td>
<td>18,500</td>
<td>15,000</td>
</tr>
<tr>
<td>Gasification Systems</td>
<td>36,051</td>
<td>36,000</td>
<td>22,000</td>
</tr>
<tr>
<td>Hydrogen Turbines</td>
<td>13,866</td>
<td>15,000</td>
<td>11,000</td>
</tr>
<tr>
<td>Coal and Coal Biomass to Liquids</td>
<td>4,621</td>
<td>5,000</td>
<td>0</td>
</tr>
<tr>
<td>Solid Oxide Fuel Cells</td>
<td>23,110</td>
<td>25,000</td>
<td>3,000</td>
</tr>
<tr>
<td><strong>Total Advanced Energy Systems</strong></td>
<td>92,438</td>
<td>99,500</td>
<td>51,000</td>
</tr>
<tr>
<td><strong>Cross-cutting Research</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant Optimization Technologies</td>
<td>12,629</td>
<td>17,025</td>
<td>7,042</td>
</tr>
<tr>
<td>Coal Utilization Science</td>
<td>23,293</td>
<td>19,000</td>
<td>23,550</td>
</tr>
<tr>
<td>Energy Analyses</td>
<td>4,711</td>
<td>950</td>
<td>850</td>
</tr>
<tr>
<td>University Training and Research</td>
<td>3,699</td>
<td>3,600</td>
<td>2,750</td>
</tr>
<tr>
<td>International Activities</td>
<td>1,286</td>
<td>1,350</td>
<td>1,100</td>
</tr>
<tr>
<td><strong>Total Cross-cutting Research</strong></td>
<td>45,618</td>
<td>41,925</td>
<td>35,292</td>
</tr>
<tr>
<td><strong>NETL Coal Research and Development</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feasibility of Recovering Rare Earth Elements</td>
<td>0</td>
<td>15,000</td>
<td>0</td>
</tr>
<tr>
<td><strong>NETL Coal R&amp;D (Other)</strong></td>
<td>33,338</td>
<td>35,011</td>
<td>34,031</td>
</tr>
<tr>
<td><strong>NETL Coal Research and Development</strong></td>
<td>33,338</td>
<td>50,011</td>
<td>34,031</td>
</tr>
<tr>
<td><strong>TOTAL CCS AND POWER SYSTEMS</strong></td>
<td>341,864</td>
<td>392,202</td>
<td>302,407</td>
</tr>
</tbody>
</table>
**CCPI**

**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 – 1M MTPY 2017 start

**ICCS Area 1**

**Summit TX Clean Energy**
Commercial Demo of Advanced IGCC w/ Full Carbon Capture
~$1.7B – Total, $450M – DOE
EOR – ~2.2M MTPY 2019 start

**FutureGen 2.0**

**Southern Company**
Kemper County IGCC Project
Transport Gasifier w/ Carbon Capture
~$4.7B – Total, $270M – DOE
EOR – ~3.0M MTPY 2015 start

**HECA**
Commercial Demo of Advanced IGCC w/ Full Carbon Capture
~$4B – Total, $408M – DOE
EOR – ~2.6M MTPY 2020 start

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

**Archer Daniels Midland**
CO₂ Capture from Ethanol Plant
CO₂ Stored in Saline Reservoir
$208M – Total, $141M – DOE
SALINE – ~0.9M MTPY 2015 start

**Petra Nova (formerly NRG)**
W.A. Parish Generating Station
Post Combustion CO₂ Capture
$775 M – Total
$167M – DOE
EOR – ~2016 MTPY 2017 start

**Leucadia Energy**
CO₂ Capture from Methanol Plant
EOR in Eastern TX Oilfields
$436M - Total, $261M – DOE
EOR – ~4.5M MTPY 2017 start
Southern Company Services
Advanced IGCC with CO$_2$ Capture

- Kemper County, MS
- 582 MWe (net) IGCC: 2 Gasifiers, 2 Siemens Combustion Turbines, 1 Toshiba Steam Turbine
- Mississippi Lignite Fuel
- ~67% CO$_2$ capture (Selexol® process) 3,000,000 tons CO$_2$/year
- EOR Denbury Onshore LLC, Treetop Midstream Services LLC
- Total Project: $4.7 Billion
DOE Share: $270 Million (6%)

Key Dates
- Project Awarded: January 2006
- Project moved to MS: December 2008
- Construction: July 2010
- NEPA ROD: August 2010
- Operations: Mid-2015

Status
- Plant construction >86% complete; >5,700 construction workers on site
- CO$_2$ off-take agreements signed
- Lignite mine under development
- Subsystem in pre-commissioning
- Combustion turbine startup: Aug 2013
- Roll Steam Turbine: Oct 2013
- Gasifier heat-up: 3rd Quarter 2014
Hydrogen Energy California (HECA)

Advanced IGCC-Polygen w/CCUS

- Kern County, CA, EOR: Elk Hills oilfield
- Up to 300 MWe (net) with load following; greenfield IGCC; Urea/UAN production
  - MHI oxygen-blown gasifier (1 x 100%)
  - MHI G-class air cooled combustion turbine (1)
- Fuel: Sub-bituminous coal/pet coke
- 90% CO₂ capture – 3,020,000 tonnes CO₂/year
  - 2.57M tonnes/y EOR; 0.45M tonnes/y Urea production
  - 2-stage Water Gas Shift, Linde Rectisol® AGR
- Use of brackish water for power production; ZLD
- Total DOE Project: $4 Billion DOE - $408 Million (10%)

Key Dates
- Project Awarded: Sep 2009
- New Owner, SCS Energy: Sep 2011
- Financial Close: Mid-2015
- Start of Construction: Late 2015
- Start of Operation: Mid-2020

Status
- Power/Fertilizer/CO₂/EPC discussions in progress
- FEED completed: Jun 2013
- Draft EIS published: July 19, 2013
- Final Determination (Air Permit) – July 2013
FutureGen 2.0
Oxy-Combustion w/ CO₂ Sequestration

- 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 tonnes 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: Jan 13, 2014
- Financial Close: Summer 2014
- Construction: Summer 2014
- Operation: Winter 2017

Status
- Storage site selected: Oct 2011
- Power plant project novated to FGA: 1/30/13
- PPA signed: Aug 2013
- FEED completed: December 2013
- UIC Class VI Draft Permit Issued: March 2014
Summit Texas Clean Energy

Advanced IGCC-Polygen w/CCUS

• Penwell, Ector County, TX
• 200 MW (net), 0.7M tonnes/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 tonnes CO₂/year
  — 2.2M tonnes/y EOR; 0.5M tonnes/y to Urea production
  — 2-stage Water Gas Shift, Linde Rectisol ° AGR
• EOR: Permian Basin Oilfields
• Total DOE Project: $1.727 Billion
  DOE Share: $450 Million (26%)
• Total Plant Cost ~$3.858 Billion (all in)

Key Dates
- Air Permit; Dec 2010
- NEPA Record of Decision: Sep 2011
- Financial Close: Mid/Late 2015
- Construction: Late 2015
- Operation: 2019

Status
- Urea contract: Jan 2011
- CO₂ contract(s): Nov 2011
- Chexim signed for debt financing
- MOU: Sep 2012
- PPA/EPC under negotiations
Petra Nova Parish Holdings (Formerly NRG)

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 Oilfield
- 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: Apr 2013
- Financial Close: June 2014
- Construction: June 2014
- Operation: 2017

Status
- EOR Host Site acquired: Oct 2011
- 240 MWe FEED completed: Feb 21, 2012
- MHI initiated detailed design: Dec 2012
- ROD approved: 2013
- CFIUS Approval Complete – Feb 2014
- Limited Notice to Proceed – March 2014
Archer Daniels Midland

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 triethylene glycol) and compression – ~900,000 tonnes CO₂/year
- Sequestration in Mt. Simon Sandstone saline reservoir
- 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: Aug 2014
- Sequestration start: March 2015

Status
- Construction ~65% complete
- Two monitoring wells drilled: Nov 2012
- Commissioning compression and dehydration: began in July 2013
- Draft UIC Class VI permit issued: April 2014
ADM - Project Photos (June 2013)

Four Compressor Train

Compressor & Auxiliaries

Dehydration System

8” High Pressure transmission Line
ADM - Project Monitoring Photos (June 2013)

Shallow Groundwater Sampling

Soil Gas and CO$_2$ Flux Networks
Leucadia Energy

**Petcoke Gasification to Methanol**

- Lake Charles, LA
- GE Energy Gasification
  (4 gasifiers: 3 hot/1 spare)
- 700 million gallons/year methanol; 110 mmscfd hydrogen
- 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: $261M (60%)

### Key Dates
- Phase 2 awarded: Jun 17, 2010
- NEPA ROD issued: Dec 2013
- Financial close: July 2014
- Construction: July 2014
- Operation: Late 2017

### Status
- Product off-take contracts finalized (BP, APCI)
- FEED in progress for gasification plant
Leucadia Site

Panoramic View of Current Site Cleared Looking South

Site preparation and drainage - Completed

Site to be raised to 10 Ft above Sea Level (Post Rita Flood Level)
Air Products & Chemicals
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 for EOR - West Hastings oilfield
• Total Project: $431 Million
  DOE Share: $284 Million (66%)

Key Dates
- Phase 2 Awarded: Jun 15, 2010
- FEED complete: Nov 2010
- Permit By Rule (PBR) and Standard Air Permits issued: May 2011
- NEPA FONSI: Jul 2011
- Construction start: Aug 2011
- Operation start: Dec 2012
- 1MMT of CO₂ Sequestered: April 2014

Status
- PA-1 initiated operation: Mar 3, 2013
- PA-2 initiated operation: Dec 16, 2012
  - Operating continuously since Dec 31, 2012
  - Full capacity achieved: April 2013
- Final MVA report submitted: Feb 2013
Six projects currently injecting CO₂
Remaining injections scheduled 2014-2015

Note: Some locations presented on map may differ from final injection location
<table>
<thead>
<tr>
<th></th>
<th>RCSP</th>
<th>Geologic Province</th>
<th>Project Description</th>
<th>Injection Started &amp; Volume to date (metric tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BIG SKY</td>
<td>Kevin Dome-Duperow Formation</td>
<td>Saline storage of naturally occurring CO₂</td>
<td>Injection to begin 2015; Volume TBD</td>
</tr>
<tr>
<td>2</td>
<td>MGSC</td>
<td>Illinois Basin-Mt. Simon Sandstone</td>
<td>Saline storage of CO₂ from ADM biofuel production</td>
<td>Injection began Nov. 2011; Volume &gt;808,000 tonnes</td>
</tr>
<tr>
<td>3</td>
<td>MRCSP</td>
<td>Michigan Basin-Niagararan Reef</td>
<td>EOR using CO₂ from gas processing plant</td>
<td>Injection began Feb. 2013; Volume &gt;328,000 tonnes</td>
</tr>
<tr>
<td>4</td>
<td>PCOR</td>
<td>Powder River Basin- Muddy Sandstone</td>
<td>EOR using CO₂ from ConocoPhillips Gas Plant</td>
<td>Injection began June 2013; Volume &gt;429,000 tonnes</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Horn River Basin-Carbonates</td>
<td>Saline storage of CO₂ from Spectra Energy gas processing plant</td>
<td>Injection to begin 2015; Volume TBD</td>
</tr>
<tr>
<td>6</td>
<td>SECARB</td>
<td>Gulf Coast – Tuscaloosa Formation</td>
<td>Saline leg of EOR; storage natural CO₂</td>
<td>Injection began 2009; Volume &gt;3,000,000 tonnes</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Gulf Coast – Paluxy Formation</td>
<td>Saline storage of amine capture CO₂ from coal-fired generation</td>
<td>Injection began Aug. 2012; Volume &gt;100,000 tonnes</td>
</tr>
<tr>
<td>8</td>
<td>SWP</td>
<td>Anadarko Basin-Morrow Sandstone</td>
<td>EOR storage of CO₂ from fertilizer and ethanol plants</td>
<td>Injection began in Fall 2013; Volume &gt;83,500 tonnes</td>
</tr>
<tr>
<td>9</td>
<td>WESTCARB</td>
<td>Regional Characterization</td>
<td></td>
<td>No large-scale injection</td>
</tr>
</tbody>
</table>

*Injection Ongoing*  
*Injection Scheduled 2014-2015*
Advanced Fossil Energy Projects Solicitation

LPO Provides Project Finance Debt Capital
- $8 Billion in Loan Guarantee Authority for Fossil Energy
- Long-Term Financing Available

What is an Advanced Fossil Energy Project?
- Projects Must Be Innovative, Utilize Fossil Energy
- Reduce Greenhouse Gas Emissions
- Located in U.S. with Reasonable Prospect of Repayment

Application Process and Dates
- **Part 1 Deadline: July 31, 2014 or December 05, 2014**
- Online Application Portal and Streamlined Review Process
# The Advanced Fossil Solicitation Covers Four Technology Areas*

**Advanced Resource Development**
- Coal-bed methane recovery
- Novel oil and gas drilling

**Low Carbon Power Systems**
- Chemical looping or process that isolate fuel from air during combustion
- Fuel cells which convert chemical energy into electricity without combustion

**Carbon Capture**
- CO₂ capture from traditional coal or natural gas electricity generation
- Permanent geologic storage or utilization in enhanced oil recovery (EOR)

**Efficiency Improvements**
- Combined heat and power (CHP) and waste recovery
- High-efficiency distributed fossil power systems, and microgrids

*Qualifying projects may include but are not limited to the technologies within.