

## Carbon Storage in DOE/NETL Major Demonstrations

Gary J. Stiegel  
Director, Major Projects Division  
Office of Major Demonstrations



# DOE's Coal RD&D Investment Strategy

## Approaches

## Programs

## Goals



### RESEARCH & DEVELOPMENT

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

### TECHNOLOGY DEMONSTRATION

Clean Coal Power Initiative  
Stimulus Activities  
*DOE – FE – NETL*

### FINANCIAL INCENTIVES

Tax Credits  
Loan Guarantees  
*DOE – LGO – IRS*

### TECHNOLOGIES & BEST PRACTICES

< 10% increase COE with CCS  
(pre-combustion)

< 35% increase COE with CCS  
(post- and oxy-combustion)

< \$400/kW fuel cell systems  
(2002 \$)

> 50% plant efficiency, up to 60%  
with fuel cells

> 90% CO<sub>2</sub> capture

> 99% CO<sub>2</sub> storage permanence

+/- 30% storage capacity  
resolution

# **CCT and CCS Demonstrations**

## ***A Critical Step for Commercial Deployment***

- **CCT and CCS demonstrations reduce technical, economic and environmental risk or uncertainty for new technology**
  - Provides the large-scale experience needed to validate pilot or smaller scale tests at the most cost-effective scale
  - Is essential for securing the multi-billion investment needed for commercial deployment of advanced coal projects
  - Assures regulators and the public that advanced CCT technology is environmentally benign and provides significant public benefit and that CCS can provide safe and permanent carbon storage
- **CCS will only be deployed commercially if:**
  - Carbon reduction is mandated by regulation or carbon emissions are monetized
  - It proves to be cost competitive with other low carbon alternatives (e.g., NGCC, nuclear)
  - Commercial risks are regarded as acceptable

*“If we can develop the technology to capture the carbon pollution released by coal, it can create jobs and provide energy well into the future.”*

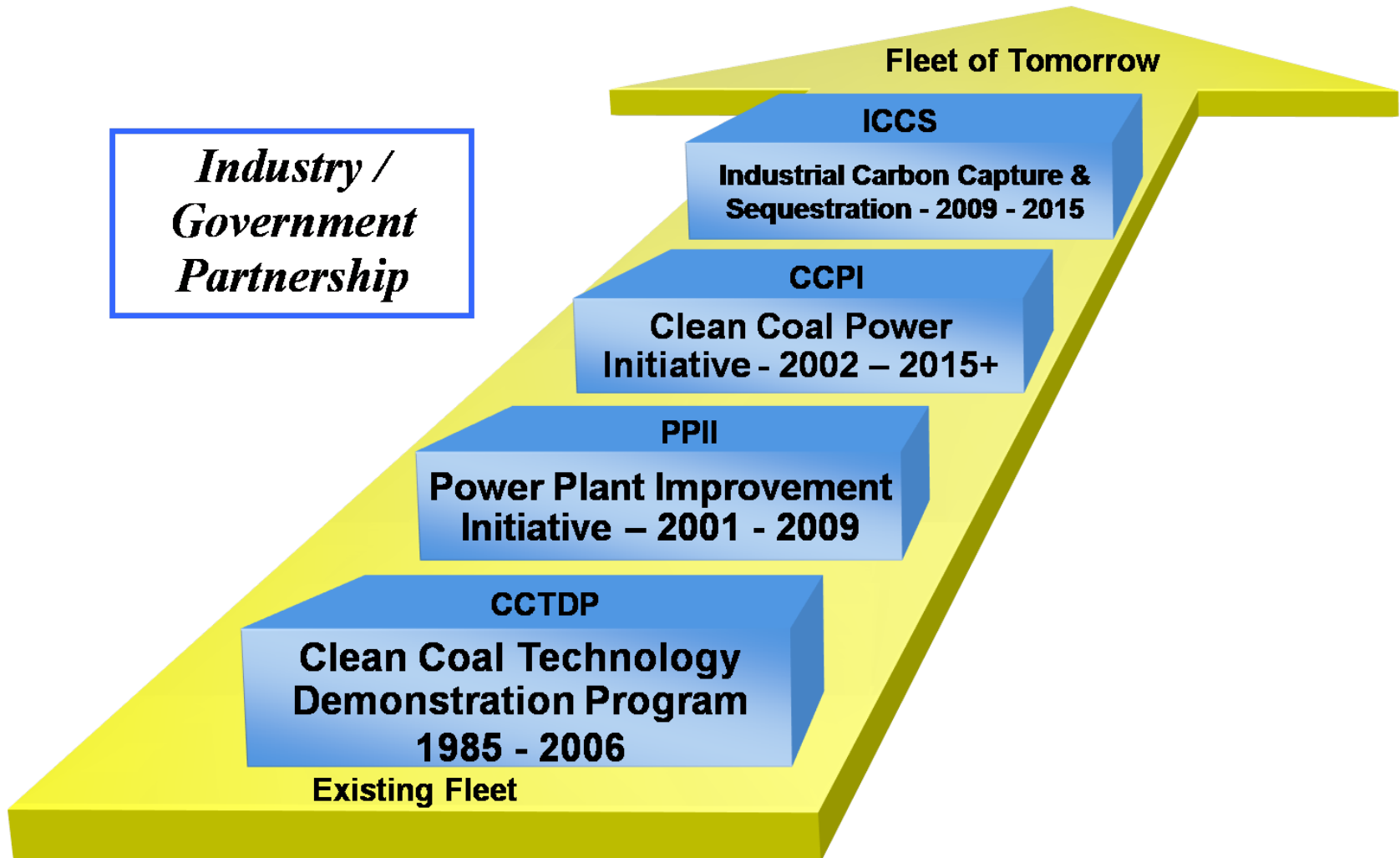
*President Barack Obama, February 3, 2010*

# Importance of CCT Demonstrations

- **Keeping the existing coal fleet in service enhances the economic security of the U.S.**
  - COE is ~\$30/MWh for existing plants vs. over \$80/MWh for new plants
  - A large fraction (over half) of existing coal plants are good candidates for retrofit of additional clean-up and CCS technology<sup>2,3</sup>
  - Retrofitting advanced CCS technology to existing plants can be the least-cost option for providing clean and low carbon power
- **CCTs can provide a low-cost option for providing additional clean electric power from domestic resources:**
  - The LCOE for new coal plants with advanced technology will compete favorably with nuclear and other low carbon options for power generation
  - Preserves U.S. manufacturing jobs by making American-made products more competitive
  - Reduces cost burden to electricity consumers in an economically challenging times<sup>1</sup>
  - Provides price stability – coal prices for utilities have been relatively stable
- **Successful demonstration of CCT/CCS technology is essential to subsequent commercial deployment**

# DOE's Major Demonstrations Program

## *A History of Innovative Projects*



# FE RD&D Performance Measures and Goals

Performance Measure	FE Performance Goals		
	Current FE R&D Program	Recovery Act FE RD&D Projects	Total Enhanced FE R&D Program
FE-1: Number and MWe of projects funded to capture CO <sub>2</sub> from anthropogenic sources	Recovery Act Targets Only – No FE R&D Program Equivalent Targets	8-10 projects, at least 3 CO <sub>2</sub> capture technologies, equivalent to 750 to 2,000 MWe	NA
FE-2: Characterize number of geological reservoirs for CO <sub>2</sub> storage		Characterize 10 geologic reservoirs, representing at least 5 types; with 0.3 - 1 billion tons of CO <sub>2</sub> capacity	
FE-3: Number of students and professionals trained for future capture and storage industry		Train 100 students conducting 40,000 research hours, and 500 Professional Development Units or Continuing Education Units (CEU)	
FE-4: Tons CO <sub>2</sub> captured and stored per year		5 million tons per year by 2015	
FE-5: Tons CO <sub>2</sub> emissions avoided	11.8 million tons by 2015	7.5 million tons by 2015	19.5 million tons by 2015
FE-6: Barrels of oil consumption displaced (Crude Oil Equivalent) per year	8.8 million barrels of foreign oil displaced per year	4 million barrels of foreign oil displaced per year	12.8 million barrels of foreign oil displaced per year

# DOE's Major Demonstrations Program

## *Current Program Objectives and Targets*

### **Clean Coal Power Initiative**

- **CCPI-3**

- Demonstrate 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<sub>2</sub> emissions
- Minimum coal or coal refuse energy input: 75% (Closing 1); 55% (Closing 2)
- Attain 90% CO<sub>2</sub> 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<sub>2</sub> or other useful products with or without electricity production
- Demonstrate sequestration with 1,000,000 tons per year of CO<sub>2</sub> emissions

### **FutureGen 2.0**

- Demonstrate oxy-combustion repowering with >1,000,000 tons per year of CO<sub>2</sub> emissions sequestered in a saline aquifer

# Major CCS Demonstration Projects

## Project Locations & Cost Share

### *FutureGen 2.0*

Large-scale Testing of Oxy-Combustion w/ CO<sub>2</sub> Capture and Sequestration in Saline Formation  
 Plant: \$737M – Total; \$590M – DOE  
 Trans. & Storage: \$553M – Total; \$459M – DOE  
 Project: ~\$1.3B – Total; ~\$1.0B – DOE  
**SALINE – 1.3M TPY 2016 start**

- CCPI
- ICCS Area 1
- FutureGen 2.0

### *Archer Daniels Midland*

CO<sub>2</sub> Capture from Ethanol Plant  
 CO<sub>2</sub> Stored in Saline Reservoir  
 \$208M – Total, \$141M – DOE  
**SALINE – ~1 M TPY 2013 start**

### *Summit TX Clean Energy*

Commercial Demo of Advanced IGCC w/ Full Carbon Capture  
 ~\$1.7B – Total  
 \$450M – DOE  
**EOR – 3M TPY 2014 start**

### *AEP - Withdrawn*

Mountaineer Power Plant  
 Post Combustion CO<sub>2</sub> Capture  
 \$668M – Total  
 \$334M – DOE  
**SALINE – 1.5M TPY 2015 start**

### *HECA*

Commercial Demo of Advanced IGCC w/ Full Carbon Capture  
 ~\$2.8B – Total, \$408M – DOE  
**EOR – 2M TPY 2018 start**

### *Southern Company*

Kemper County IGCC Project  
 IGCC-Transport Gasifier w/Carbon Capture  
 ~\$2.67B – Total  
 \$270M – -DOE  
**EOR – 3 M TPY 2014 start**

### *NRG*

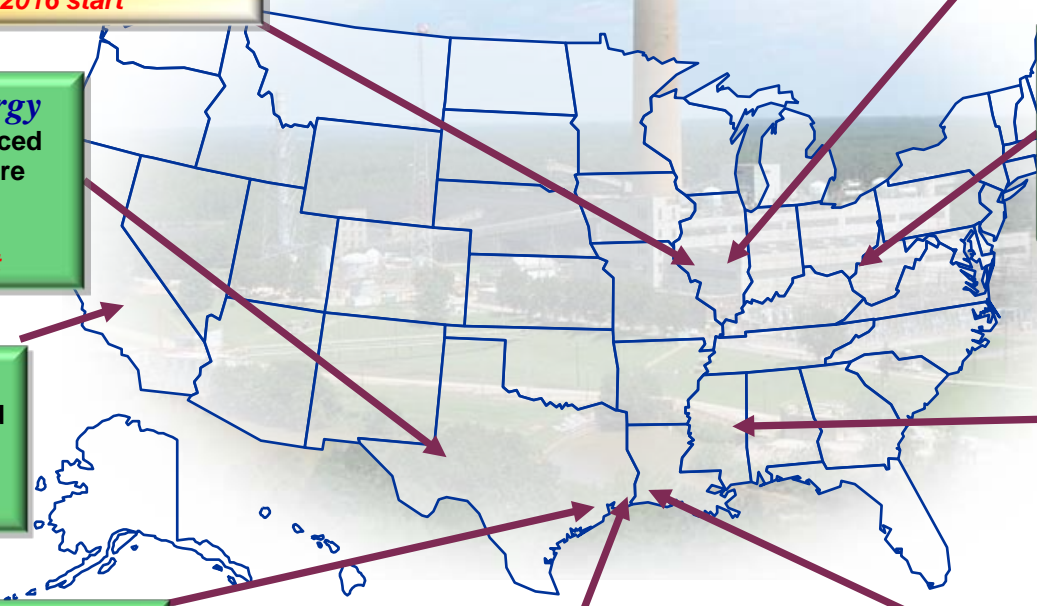
W.A. Parish Generating Station  
 Post Combustion CO<sub>2</sub> Capture  
 \$339M – Total  
 \$167M – DOE  
**EOR – 1.4M TPY 2014 start**

### *Air Products and Chemicals, Inc.*

CO<sub>2</sub> Capture from Steam Methane Reformers  
 EOR in Eastern TX Oilfields  
 \$431M – Total, \$284M – DOE  
**EOR – 1M TPY 2013 start**

### *Leucadia Energy*

CO<sub>2</sub> Capture from Methanol Plant  
 EOR in Eastern TX Oilfields  
 \$436M - Total, \$261M – DOE  
**EOR – 4 M TPY 2014 start**





# Portfolio of Capture and Storage Approaches

	Plant Type		Sequestration		Feedstock
	Power	Industrial	Saline	EOR	
<b>Pre-combustion</b>					
<b>HECA (IGCC-Polygen)</b>	X	X		X	Coal/Coke blend
<b>Southern-Kemper Co. (IGCC)</b>	X			X	Lignite, MS
<b>Summit Texas (IGCC-Polygen)</b>	X	X		X	Coal, sub-bituminous, WY
<b>Leucadia, Lake Charles (Methanol)</b>		X		X	Petroleum coke
<b>Air Products and Chemicals, Inc. (SMR)</b>		X		X	Natural gas
<b>ADM (Capture from Biofuels)</b>		X	X		Ethanol production from biomass
<b>Post-combustion</b>					
<b>Mountaineer</b>	X		X		Coal, bituminous
<b>NRG Energy</b>	X			X	Coal, sub-bituminous, WY
<b>Oxy-combustion</b>					
<b>FutureGen 2.0</b>	X		X		Coal

 CCPI

 ICCS Area 1

 FutureGen 2.0

# *Clean Coal Power Initiative (CCPI)*

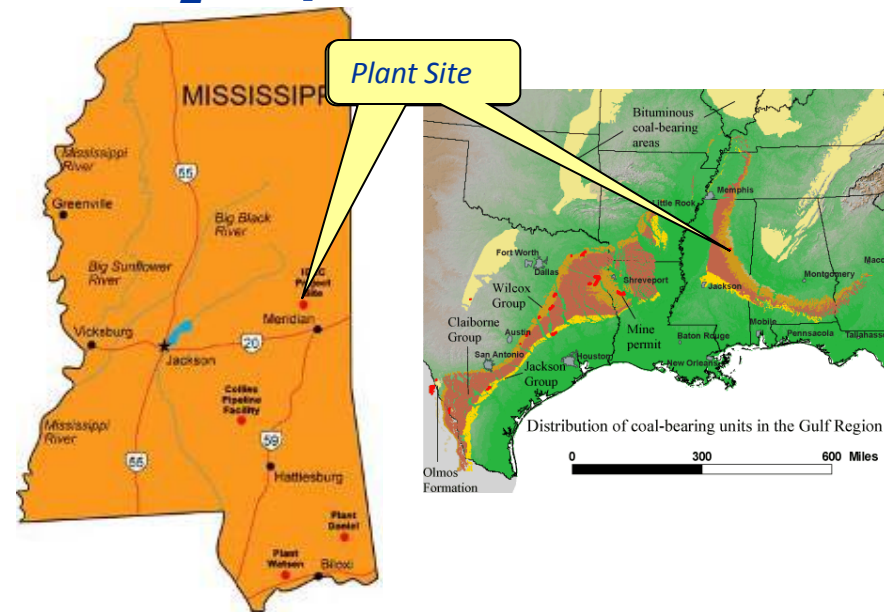
# CCPI Active CCS Projects

CCPI Round	Project	Recipient	CO <sub>2</sub> Capture Technology	Sequestration	CO <sub>2</sub> Seq. (TPY)	Seq. Start
CCPI-2	Kemper	SCS	Selexol®	EOR	3,000,000	2014
CCPI-3	HECA	HECA	Rectisol®	EOR	2,500,000	2018 (est.)
CCPI-3	Mountaineer	AEP	Chilled Ammonia Process	Saline	1,500,000	2015
CCPI-3	WA Parish	NRG Energy	Fluor Econamine FG Plus <sup>SM</sup>	EOR	1,400,000	2014
CCPI-3	TCEP	Summit	Rectisol®	EOR	3,000,000	2014

# Southern Company Services, Inc. CCPI-2

## Advanced IGCC with CO<sub>2</sub> Capture

- Kemper County, MS
- 582 MWe (net) IGCC: 2 KBR Transport Gasifiers, 2 Siemens Combustion Turbines, 1 Toshiba Steam Turbine
- Mississippi Lignite Fuel
- ~67% CO<sub>2</sub> capture (Selexol® process)  
3,000,000 tons CO<sub>2</sub>/year
- EOR Sequestration site TBD (Start 2014)
- Total Project: \$2.01 Billion  
DOE Share: \$270 Million (13%)



### Key Dates

- Project Awarded: Jan 2006
- Project moved to MS: Dec 2008
- Construction: Jul 2010
- NEPA ROD: Aug 2010
- Operations: May 2014

### Status

- NEPA Record of Decision: 8/19/2010
- Construction initiated: 9/16/2010
- Process equipment installation beginning

# Southern Company Services, Inc. CCPI-2

## *Construction Status - October 2011*



# Southern Company Services, Inc. CCPI-2 Gasifier and Fluid Bed Dryer Housing



*Gasifier Fit-up and Welding*



*Heat Exchanger Housing<sup>42</sup>*



*Dryer Housing*



# Southern Company Services, Inc. CCPI-2

## Construction Status, October 2011



*Warehouse Facility*



*Turbine Generator Pedestal*



*Electrical Duct Bank*



*Coal Mill Foundations*

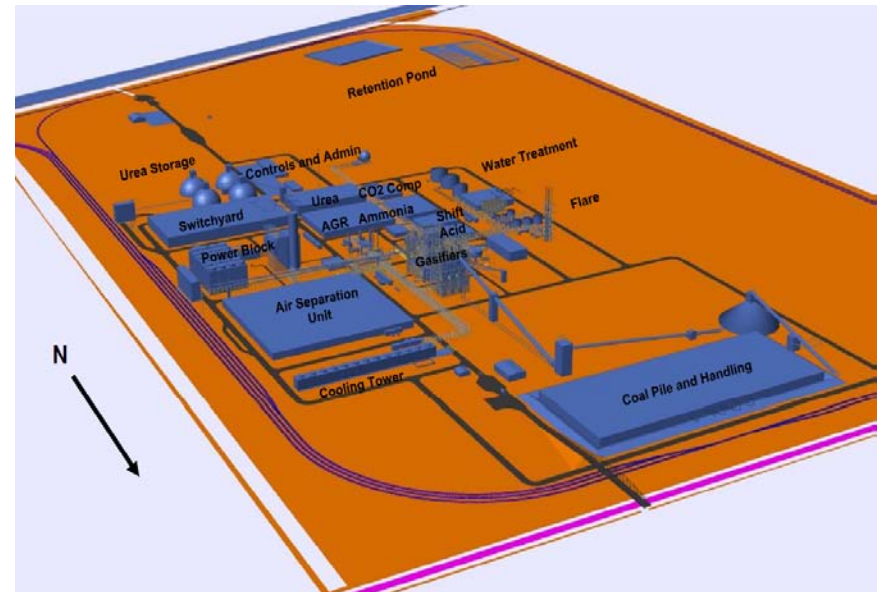
# Summit Texas Clean Energy, LLC CCPI-3

## Advanced IGCC-Polygen

- Penwell, Ector County, TX
- 400 MWe (gross) Greenfield IGCC with Siemens Gasification and Power Block
  - SFG-500 gasifiers (2 x 50%)
  - High H<sub>2</sub> SGCC6-5000F combined cycle (1 x 1)
- PRB sub bituminous coal fuel
- 90% CO<sub>2</sub> capture – 3,000,000 tons CO<sub>2</sub>/yr
  - 2-stage Water Gas Shift
  - Linde Rectisol® AGR
- Permian Basin EOR (Start: 2014)
- Total Project: \$1.727 Billion  
DOE Share: \$450 Million (26%)

### Key Dates

- Project Awarded: Jan 2010
- Construction: Jun 2012
- Financial Close: 1<sup>st</sup> Q FY2012
- Operation: Jul 2014



### Status

- Air permit: Dec 2010
- Urea contract: Jan 2011
- CO<sub>2</sub> contract (60% of total): May 2011
- Power off-take term sheet: Jun 2011
- Record of Decision: Sep 2011
- Negotiating project financing



# Hydrogen Energy California

## *Advanced IGCC-Polygen*

- Kern County, CA
- Up to 280 MWe (net) IGCC, 1.0 MT/yr Urea/UAN
- 90% CO<sub>2</sub> capture – 2,500,000 tons CO<sub>2</sub>/year
- EOR - Elk Hills oil field (Start: TBD)
- Fuels: Bituminous Coal/Petcoke
- Maximize use of non-potable water for power production
- Recycle all IGCC/project wastewater with 100% zero liquid discharge
- Total Project : \$4.0 Billion  
DOE - \$408 Million (10%)



### Key Dates

- Project Awarded: 9/30/2009
- Project Being Re-baselined

### Status

- New Owner, SCS Energy: 9/2011
- FEED initiated: 9/21/2011

# American Electric Power Co. (AEP) CCPI-3 *Advanced Post Combustion CO<sub>2</sub> Capture*

- New Haven, WV
- 235 MWe slipstream at AEP's 1300 MWe Mountaineer Plant
- 90% CO<sub>2</sub> capture (Alstom Chilled Ammonia Process) 1,500,000 tons CO<sub>2</sub>/year
- Deep saline sequestration in the Rose Run and Copper Ridge formations (Start: 2015)
- Total Project: \$668 Million
  - DOE Share: \$334 Million (50%)
    - \$146 Million ARRA
    - \$188 Million Non-ARRA



## Key Dates

- Project Awarded: Jan 2010
- FEED Complete: Sep 2011
- Construction: Jan 2013
- Operation: Dec 2015

## Status

- FEED Completed: Sep 2011
- NEPA: Draft EIS completed; on hold
- Project Postponed: Cooperative Agreement ended 9/30/2011

# W.A. Parish NRG Energy CCPI-3 *Advanced Post Combustion CO<sub>2</sub> Capture*

- Thompsons, TX (near Houston)
- 240 MWe slipstream at NRG Energy's W.A. Parish power plant
- PRB sub bituminous coal fuel
- 90% CO<sub>2</sub> capture (Fluor's Econamine FG Plus<sup>SM</sup> process) 400,000 tons CO<sub>2</sub>/year
- Texas Gulf Coast EOR (Start: 2014)
- Total Project: \$339 Million  
DOE Share: \$167 Million (49%)



## Key Dates

- Project Awarded: May 2010
- Construction: Dec 2012
- Operation: Dec 2014

## Status

- 60 MWe FEED almost complete
- Project being scaled up to improve economics
- Initiated 240 MWe FEED: 5/3/2010
- Acquisition of EOR Host Site Completed: 10/3/2011
- NEPA Public Scoping Meeting Scheduled: 11/30/2011, 12/1/2011

# ***Industrial Carbon Capture & Storage (ICCS)***

# CO<sub>2</sub> Capture from Industrial Sources

## *Low Hanging Fruit*

- Globally, industry accounts for 40% of energy-related CO<sub>2</sub> emissions -- mostly in developing countries\*
- Many industrial facilities are large point sources
- In some plants, CO<sub>2</sub> is already being captured in order to produce the desired product (e.g., H<sub>2</sub>/NH<sub>3</sub>), and additional capture cost is not incurred
- CO<sub>2</sub> concentration in treated stream may be high or nearly pure
- Often located near potential storage sites
- Demonstration of capture and compression technology, as well as CO<sub>2</sub> storage experience, is applicable to coal-fired power generation



Hanson Permanente Cement Kiln, Los Altos, CA, 2008

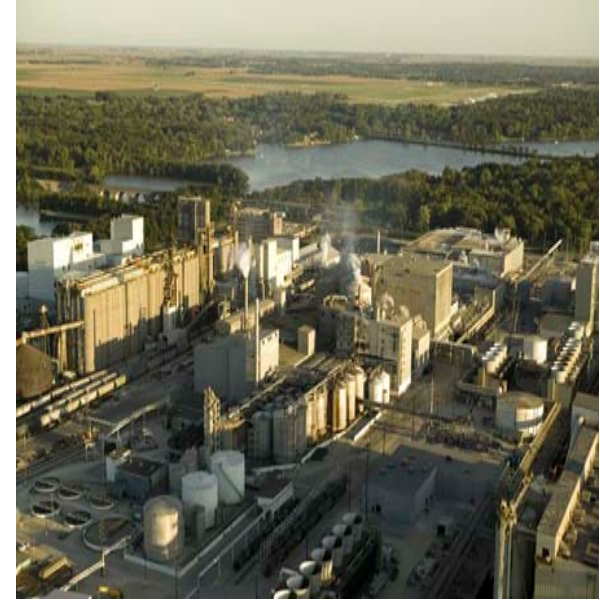
# Active ICCS Area 1 Projects – Phase 2

Project	Recipient	CO <sub>2</sub> Capture Technology	Sequestration	CO <sub>2</sub> Seq. (TPY)	Seq. Start
Fermentation CO <sub>2</sub>	ADM	N/A	Saline	1,000,000	2013
SMR H <sub>2</sub> Production	APCI	VSA	EOR	1,000,000	2013
Methanol from Petcoke Gasification	Leucadia Energy, LLC	Rectisol®	EOR	4,500,000	2014

# Archer Daniels Midland Company ICCS Area 1

## *CO<sub>2</sub> Capture from Biofuel Plant*

- Decatur, IL
- CO<sub>2</sub> is a by-product (>99% purity) from production of fuel grade ethanol via anaerobic fermentation
- Up to 90% CO<sub>2</sub> capture; dehydration (via triethylene glycol) and compression – 1,000,000 tons CO<sub>2</sub>/year
- Sequestration in Mt. Simon Sandstone saline reservoir (Start: July 2013)
- Total Project: \$208 Million  
DOE Share: \$141 Million (68%)



### Key Dates

- Phase 2 Awarded: Jun 15, 2010
- FEED Complete: Apr 2011
- Construction: May 2011
- Operation: Jul 2013

### Status

- Detailed design in progress
- NEPA completed
- Construction in progress
- UIC Class VI permit submitted: 7/26/2011

# Archer Daniels Midland Company ICCS Area 1

## Construction Status – October 2011



*Switchgear Building*



*Ground Water Well*



*Compressor Building*



*Alternate Power Supply*



# Air Products and Chemicals, Inc. ICCS Area 1

## Steam Methane Reforming with CO<sub>2</sub> Capture

- Port Arthur, TX (Hydrogen plant at Valero Refinery)
- 90% CO<sub>2</sub> capture (Vacuum Swing Adsorption) from 2 steam-methane reformers (SMRs) yielding >1,000,000 tons CO<sub>2</sub>/year
- ~28 MWe cogeneration unit to supply makeup steam to SMRs and operate VSA and Compression Equipment
- CO<sub>2</sub> to Denbury pipeline for EOR in West Hastings oil field (Start: 2012)
- Total Project: \$431 Million  
DOE Share: \$284 Million (66%)



### Key Dates

- Phase 2 Awarded: Jun 15, 2010
- FEED Complete: Nov 2010
- Construction: Aug 2011
- Operation: Jan 2013

### Status

- CO<sub>2</sub> off-take agreement executed with Denbury; CO<sub>2</sub> capture and utilities agreement executed with Valero
- Permit By Rule (PBR) and Standard Air Permits Issued by TCEQ: May 2011
- Phase 2B authorized by NETL: 6/1/2011
- FONSI Issued: 7/8/2011
- Construction in progress

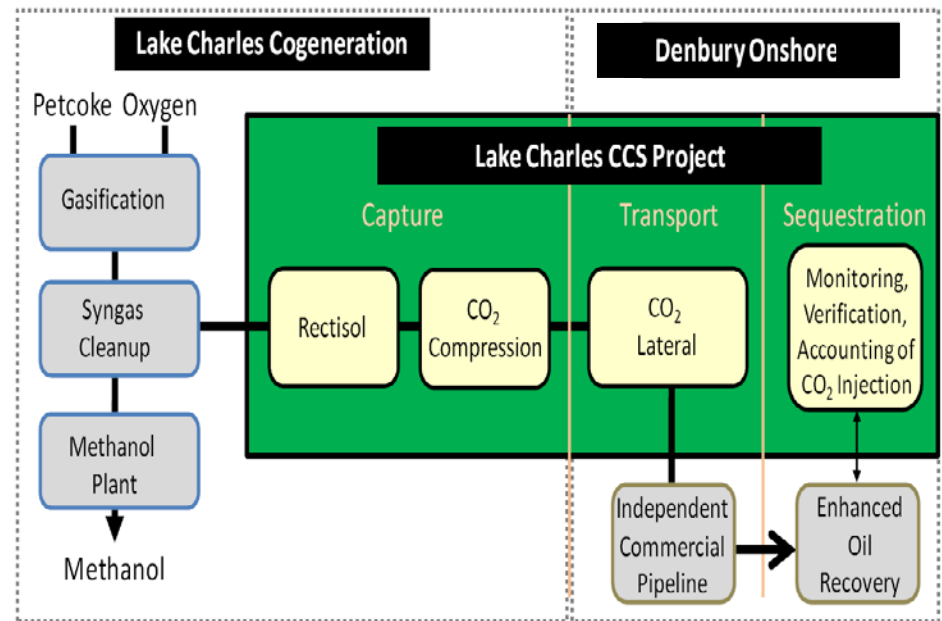
# Air Products and Chemicals, Inc. ICCS Area 1 Construction Status – November 2011



# Leucadia Energy, LLC ICCS Area 1

## *Petcoke Gasification to Methanol*

- Lake Charles, LA
- GE Energy Gasification (5 gasifiers: 4 hot/1 spare)
- 730 Million gallons/year methanol
- 90% CO<sub>2</sub> capture (Rectisol® process); 4,500,000 tons CO<sub>2</sub>/year
- CO<sub>2</sub> to Denbury pipeline for EOR in Texas at the West Hastings oil field (Start 2015)
- Total Project: \$436 Million  
DOE Share: \$261 Million (60%)



### Key Dates

- Phase 2 Awarded: Jun 17, 2010
- Complete FEED: Jun 2011
- Construction: Oct 2012
- Operation: Jun 2015

### Status

- FEED in progress
- NEPA EIS in progress
- Negotiating product off-take agreements

# *FutureGen 2.0*

# FutureGen 2.0

## *Oxy-Combustion w/ CO<sub>2</sub> Sequestration*

- Meredosias, IL and Morgan Co., IL
- 200 MWe gross oxy-combustion repowering of Ameren's Meredosias Unit 4 steam turbine (Start 2016)
- 90% CO<sub>2</sub> capture (cryogenic separation) 1,300,000 tons CO<sub>2</sub>/year
- Deep saline sequestration in Mt. Simon formation
- Total Project: \$1.3 Billion  
DOE Share: \$1.05 Billion (81%)



### Key Dates

- Complete FEED: Oct 2012
- Construction: Nov 2012
- Operation: May 2016

### Status

- Pre-FEED in progress
- Sequestration site characterization and validation In progress
- NEPA in progress, public scoping meetings 2<sup>nd</sup> Q CY2011

# For Additional Information

U.S. DEPARTMENT OF ENERGY

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